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Symposium on Anesthesia

FACTORS INFLUENCING TRENDS IN ANESTHESIA

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MANY factors have influenced the use of agents and methods in the production of anesthesia for surgical, obstetric, and dental patients. Obviously, one of the most important was the discovery of an agent or method. The work of Morton and Long gave ether anesthesia its start and the work of Horace Wells gave nitrous oxide its start. Other agents have been introduced in this first century of anesthesia and have influenced the trend in anesthesia practice, sometimes only briefly but sometimes very markedly. For example, Gwathmey's contribution of mixing oil and ether and later the introduction of tribromethanol in amylene hydrate (avertin) advanced the use of the rectal method very definitely. Several pioneers advanced the cause of local, regional, and spinal anesthesia. The contribution of the hollow hypodermic needle helped to make intravenous anesthesia possible. The vast amount of research on the various barbiturates resulted in the production of pentothal sodium, an agent that is extensively used today. The development of gas machines had a marked influence on the use of anesthetics, particularly the addition of the soda lime absorber for removal of carbon dioxide. Magill's contribution of his intratracheal tube was a landmark in the improvement of inhalation anesthesia. There are many other influencing factors that are perhaps less obvious, such as societies composed of those interested in the administration of anesthetics, periodicals and textbooks on the subject, and the organized teaching centers for clinical teaching and research.

The special circumstances and environment which characterize the various medical schools and hospitals throughout the country are very important factors with respect to anesthesia. The policy of the superintendent of a hospital may be reflected in the methods of anesthesia that are made available to the staff. For example, if the anesthetist can administer only inhalation anesthetics, then the surgeon must himself provide any other type of anesthesia that he would like to use. If the surgeon is only an occasional user of a method he may give it up as being unsatisfactory if he cannot carry it out well. Quite often the patient has a preference for a certain agent or may be antagonistic to a method. For example, many patients do not want to submit to ether

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anesthesia and others refuse to submit to spinal anesthesia. Some patients are so excited that heavy doses of preliminary medication may be resorted to. This also influences one's choice of anesthetic and tends to make the use of ether by inhalation, for example, unsatisfactory.

The surgeon has, as a rule, a very definite opinion about the anesthetic of choice. Unless he reposes enough confidence and responsibility in the anesthetist so that the anesthetist may choose and use a certain anesthetic, the choice will be dictated by the surgeon. In time this factor will decrease the anesthetist's enthusiasm for maintaining his skill with a variety of agents and methods.

Anesthesia at the Mayo Clinic in the last fifty years has been influenced by a variety of circumstances that have been described elsewhere.¹ Ether and chloroform were first used. Nitrous oxide was used in 1900 but because of the fact that a heavy preliminary medication of scopolamine was used the color of the patient was unsatisfactory and the agent was not used again until 1918. At this time it was used for dental surgery and it has been used ever since for all types of operations.

When ethylene was introduced in 1923 it was used extensively at the clinic. Rectal anesthesia was given a trial in the early twenties. Magill's method of intratracheal anesthesia using the large bore, soft rubber tube was adopted in 1930. Cyclopropane was used in 1933. In 1929 the intravenous method of using sodium amytal was reported on and it was tried here in 1930. In 1931 one of us (J. S. L.) reported on the intravenous use of pentobarbital sodium (sodium nembutal). In 1933 evipal was used and in 1934 pentothal sodium was introduced here. Other agents that were not anesthetics, such as carbon dioxide, were employed from the beginning of 1924. Intocostrin for the production of relaxation, particularly for abdominal operations, was first used here in 1943.

Of the local anesthetics, procaine hydrochloride has remained the favorite, with metycaine hydrochloride a close second. Pontocaine hydrochloride and nupercaine hydrochloride have been tried and discarded. The introduction of Lemmon's method of continuous spinal anesthesia and Hingson's method of continuous caudal anesthesia has made it possible to obtain long-lasting anesthesia by repeated injections of procaine so that long-lasting anesthetics were not essential.²

As each agent and method has been introduced and tried, certain benefits were realized and certain unexpected and sometimes untoward results have been experienced. In consequence, there has been less tendency to advocate the use of any certain anesthetic agent or method and there has been a tendency to avoid strongly the use of certain drugs. For the most part, if a local anesthetic is used and is unsatisfactory it is then supplemented with gas anesthesia with or without intravenous anesthesia. If gas anesthesia is unsatisfactory, then usually one resorts to diethylether. In most cases the use of ether by the semi-open-drop method produces good results, especially if Magill's intratracheal tube can also be used.

The question is often asked of us: "Why do you use a certain agent or method so much or so little?" The simplest way to indicate the proper answer to such a question is to present the statistics that are available for the last twenty years concerning anesthetic agents and methods in our hands.

In Table I both the actual figures and the percentages are shown. The use of ordinary methods refers to ether by the semi-open-drop method; nitrous

TABLE I. COMPARISON OF USE OF SPECIAL AND OF ORDINARY AGENTS AND METHODS

YEAR	CASES			PER CENT	
	SPECIAL	ORDINARY	TOTAL	SPECIAL	ORDINARY
1924	1,169	16,370	17,539	6.7	93.3
1925	3,302	17,453	20,755	15.9	84.1
1926	3,478	17,782	21,260	16.4	83.6
1927	2,825	18,948	21,773	13.0	87.0
1928	3,163	18,412	21,575	14.7	85.3
1929	4,002	16,848	20,850	19.2	80.8
1930	5,662	13,930	19,592	28.9	71.1
1931	5,528	11,962	17,490	31.6	68.4
1932	4,218	9,685	13,903	30.3	69.7
1933	4,348	9,672	14,020	31.0	69.0
1934	5,779	10,639	16,418	35.2	64.8
1935	9,056	8,270	17,326	52.3	47.7
1936	13,397	5,503	18,900	70.9	29.1
1937	12,222	7,949	20,171	60.6	39.4
1938	13,411	7,843	21,254	63.1	36.9
1939	14,918	6,828	21,746	68.6	31.4
1940	15,428	6,739	22,167	69.6	30.4
1941	15,146	8,757	23,903	63.4	36.6
1942	17,997	6,551	24,548	73.3	26.7
1943	18,443	9,749	28,192	65.4	34.6

oxide with or without ether; nitrous oxide, oxygen, and ether; ethylene and oxygen with or without ether, and the use of procaine by infiltration or use of topical anesthetics by the surgeon or his assistant. Under the title of "special methods" are those in the application of which special personnel is employed: for example, spinal and regional anesthesia that is administered by the professional anesthetist, as well as intravenous anesthesia, intratracheal anesthesia, cyclopropane, curare, and so forth. In 1924 special measures were employed in less than 7 per cent of the administrations. In Table II it will be noted that in 1924 whatever special methods were used were those in which regional anesthesia was employed. In Table III it may be seen in the over-all survey of the use of the various agents in 1924 that they fall primarily into three groups: (1) local anesthesia, (2) ether by the open-drop method, and (3) gases with or without ether. This limitation in choice of anesthesia was one of the reasons for institution in that year of a change of plan on the part of the management of the Mayo Clinic looking forward to the time when there would be a large choice of anesthetics and adequate personnel for their administration.³

One of us (J. S. L.) undertook to start this program on March 27, 1924, and since that time several associates, assistants, and students have collaborated in the effort up to the present time. The surgical staff has been a major influence in this program and, as that staff has changed, certain changes in the program have occurred. The older surgeons had used ether by the drop method almost exclusively and some of the younger men without that experience were not so enthusiastic about ether as were their elders. Some wished to indicate the type of anesthetic to be used on every patient they operated on; others wished the Section on Anesthesiology to recommend what type of anesthetic should be used. In general, in spite of a gradual changing of personnel both in surgical staff and in the anesthesiology staff, certain agents and methods have been introduced from time to time and it has been the policy of the Section on Anesthesiology not to ride a hobby or encourage the use of any one agent or method to the exclusion of others. It was felt that if the agent or method had merit it would survive. The greater the merit, the more extensively would the method be used.

TABLE II. SPECIAL AGENTS AND METHODS, PER CENT

	1943	1942	1941	1940	1939	1938	1937	1936*	1935	1934	1933	1932	1931	1930	1929	1928	1927	1926	1925	1924
Regional block*	38.5	37.2	37.9	40.4	39.5	39.7	42.1	38.5	38.3	79.9	81.1	80.8	86.7	83.8	79.1	95.2	94.4	99.1	99.8	100
Oil-ether colonic																				
Acetylene																				
Tribromethyl alcohol and barbiturates																				
Barbiturates (by rectum)																				
Barbiturates (intra-venously)	35.8	38.9	42.6	43.5	39.8	31.2	31.5	20.4	14.9	2.6	0.3	0.6	1.4	8.9	15.2					
Tribromethyl alcohol	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.03	0.03	0.2	1.3	2.2	0.7	0.8	0.3					
Intratracheal anesthesia	18.2	18.4	15.4	13.8	13.9	13.1	12.1	8.0	10.2	14.8	16.2	15.5	10.4	5.2	2.9					
Intrapharyngeal anesthesia																				
Cyclopropane	2.4	2.4	2.2	1.1	0.23	0.8	0.2	0.2	0.1	0.3	0.2	0.6	0.5	0.7	0.3					
Divinyl ether	5.0	2.9	1.7	1.0	6.3	15.0	13.9†	32.6	16.3	1.7	0.3									
							0.01	0.01	0.01		0.1									

*This decrease in the percentage of cases in which regional anesthesia was employed does not mean that there was a decrease in the actual number of cases in which it was employed, for in 1933 it was used in 3,537; in 1934, in 1,621; in 1935, in 5,271; in 1936, in 5,166; and in 1937, in 5,136.

†Fifty per cent of total number of administrations of cyclopropane are considered "special agent" and 50 per cent are considered "ordinary agent."

TABLE III. AGENTS, COMBINATIONS OF AGENTS, AND METHODS USED IN ANESTHESIA, PER CENT

	1943	1942	1941	1940	1939	1938	1937	1936	1935	1934	1933	1932	1931	1930	1929	1928	1927	1926	1925	1924
Local (spinal excluded)	23.4	23.1	24.2	22.3	20.2	29.1	29.2	31.0	32.5	33.0	32.4	33.9	30.0	37.2	36.2	40.3	40.2	42.7	45.0	43.2
Local and ether (spinal included)	0.01	0.01	0.02	0.03	0.03	0.05	0.02	0.05	0.04	0.03	0.17	0.1	0.2	0.11	0.18	0.26	0.3	0.8	1.7	1.4
Local and gases (with or without ether; spinal included)																				
Spinal only	11.4	10.0	10.5	10.8	12.05	9.3	5.9	11.2	11.6	10.3	8.9	9.5	11.7	10.6	8.0	9.96	11.6	11.4	4.1	0.9
Ether (by open-drop method)	11.3	10.0	8.8	6.6	8.05	8.2	10.8	10.4	12.5	13.2	11.8	10.1	16.4	9.3	4.59	1.19	0.4			0.01
Gases (with or without ether)	0.9	0.5	0.3	0.5	0.59	0.7	0.6	0.5	0.5	0.8	2.7	3.5	5.5	7.09	15.2	16.7	19.6	19.1	20.3	44.4
Barbiturates, intra-venously and rectally	29.7	30.8	27.6	27.6	28.9	31.6	30.8	31.7	34.8	41.4	43.4	41.5	35.1	30.6	31.0	30.1	26.9	25.3	28.4	27.6
Tribromethyl alcohol	13.6	14.4	15.5	17.2	19.9	19.7	17.9	13.4	6.6	0.8	0.07	0.1	0.1	0.11	1.24					
Ethyl chloride (as general anesthetic)	0.07	0.1	0.1	0.1	0.12	0.1	0.06		0.005	0.03	0.07	0.05	0.01	0.09	0.009					
Oil-ether colonic												0.007	0.02	0.01	0.27	0.26	0.08	0.1	0.01	0.5
Chloroform										0.01					0.57	0.38	0.6	0.1	0.01	
																	0.3	0.1	0.09	

*This table includes only those cases in which the agent, combination, or method named was the only one used; that is, unless otherwise indicated.

The results are apparent in these three tables. In Table I it will be noted that special agents and methods have come to be used in about two-thirds of the cases. Ordinary agents and methods are used in about one-third of the cases and this has been true for the last seven or eight years. In Tables II and III it will be seen clearly that a mixture of oil and ether by rectum has been used but little. It has not been used at all for the last fourteen years. There were several reasons for discontinuing the use of oil and ether by rectum. The anesthesia was not always satisfactory, the method did not fit into the general scheme of things utilized by local hospitals for the handling of patients, that is, bringing them to the operating room in a wheel chair and so forth, patients often expelled some of the agent, the dose had to be guessed at and might be either too much or too little, and the percentages of such cases were high enough so that the method was not uniformly satisfactory. These remarks should not be construed to mean that it is not possible to anesthetize a fairly high percentage of patients by this method with considerable satisfaction if an experienced anesthetist is available and can devote his full attention to one case at a time. However, while it is not a mortal reflection on the method that it requires the full attention of an experienced anesthetist throughout the period of administration, nevertheless such a method is not economically as desirable as some other method in which one experienced person can supervise its use in the hands of several less skilled persons. It is used only rarely for surgical cases now but is occasionally useful in anesthetizing patients suffering from an attack of intractable asthma.

Tribromethyl alcohol as a rectal anesthetic was used here in 1929 and was more satisfactory than oil and ether by rectum. The use of barbiturates by rectum plus tribromethyl alcohol was tried but did not have any apparent advantage over tribromethyl alcohol itself and this combination was used but for a short time.

A different situation concerned the use of acetylene. It was used a few times in 1928, 1929, and 1930. About the same time it was being used in Germany under the name of nareylen. The advantages of the method were that the use of ether could be avoided and large quantities of oxygen could be administered. The hazard of explosion was very great and for that reason its use was discontinued. Since that time other agents and methods have appeared which make it neither necessary nor desirable to use acetylene again.

The intravenous use of barbiturates was begun in 1929 with sodium amytal. The results were both encouraging and discouraging. The patients liked the method but the postoperative restlessness was too great. In 1930, pentobarbital sodium (sodium nembutal), another barbiturate, was tried. Although for a time it seemed to be better than sodium amytal, still the results were not satisfactory so that by 1933 the intravenous method was practically not being used. In 1934 we began the use of pentothal sodium and since 1937 it has been employed in about one-third of all cases in which special methods of anesthesia were used. It seems that, now that the method is rather thoroughly established, its usefulness is fairly well known and its percentage of use does not vary much from year to year.⁴ This, as in the case of other agents and methods, would indicate a joint opinion of surgeons and anesthetists on this point in this institution.

Divinyl ether was tried in 1933, again in 1935, and again in 1937 in a few cases, but it had no advantages from our point of view over intravenous anesthesia and so it has not been used for the last six years. Cyclopropane,

use of which was begun in 1933, has had a considerable change in percentage of use from time to time. The explosion hazard is well recognized and there are some other effects cyclopropane seems to have on some patients that have made us guarded in the use of it, namely, sudden collapse at the end of the operation when the anesthetic was discontinued in some very prolonged and major procedures. We have heard about such episodes from others but have seldom observed them ourselves. The reports of fibrillation due to the drug have made us cautious, although actually we seldom have encountered this result clinically. It would appear that, if one observes the recommended precautions⁵ in the use of cyclopropane, it is a widely useful agent but it is not an essential except in a limited field, particularly thoracic surgery.

One outstanding method begun in 1920 was the use of Magill's intratracheal tube. Its use has greatly enhanced the value of the inhalation anesthetic agents and has provided an adequate airway under almost all circumstances in which improvement in patency of the airway was needed. The intratracheal method has survived vicissitudes associated with the placing of the tube, which involved in some cases broken teeth or trauma to the respiratory passages or both.

Such agents as chloroform and ethyl chloride by inhalation have not survived because of the fact that the risk of death associated with their use was considered to be unjustified because there are now other kinds of agents for anesthetizing patients in cases in which these agents previously were used.

From Table III it is seen that for the last eight years there has been little change in the percentage of employment of the agents used at present. It has been the joint experience of the anesthetist and the surgeon that under the circumstances under which we work, which are all-inclusive, we get our best all-around results by using certain agents and methods with the indicated frequency. We do not consider that our use of these agents and methods is necessarily the best use of them elsewhere. We recognize that in the various other medical centers there are definite reasons for using various agents and methods differently than is done here.

Many factors are involved in the choice of anesthetic which cannot be elaborated here, such as the speed that various operating surgeons employ in one institution as compared with another, the necessity for well-organized and co-ordinated work on the part of both the anesthetists and the surgeons for the satisfactory handling of a large number of patients, an abundant supply of materials and personnel in contrast to a lack of these things, and the personal enthusiasm or prejudice of either the surgical or anesthesiologic staff for or against a given agent or method. All these things make for a difference in statistics in different institutions. It does not seem necessary to argue that one institution is wrong if it does not follow the lead of another.

One agent about which there might be controversy may be selected as an example for discussion. The one selected will be diethyl ether by inhalation with or without the use of an intratracheal tube. In Table III it will be seen that there has been little change in the frequency with which ether was used for the last eight or nine years. However, if a visitor happens to observe during a period of a few days when ether is used frequently by the open-drop method, he may gain the impression that this is the standard practice although actually the agent may have been used oftener at that particular period than at any other time during the year. If ether were obviously undesirable in the cases in which it has been used, even though this conclusion might not have

been very clear twenty-five years ago, it would have become very clear now or in the last few years. Since practically any agent or method that is available anywhere is available here and since the members of the staff visit other institutions and attend meetings, they have the opportunity to see the results obtained elsewhere and after discussing the results observed elsewhere they may decide to try that technique here. This has been done repeatedly with practically all combinations of anesthetics and if the results then obtained were superior to those obtained previously then the method has survived and the old one is abandoned. In examining the figures in Tables II and III it must be clear at least for the last several years that the agents and methods employed and the methods of administration have been generally satisfactory to those concerned. The figures show more trend to use special methods whenever these methods have given better results than were obtained with ordinary methods.

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EXPLOSIONS IN ANESTHESIA

A REVIEW OF THE LITERATURE

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EXPLOSIONS have been witnessed by many anesthetists and surgeons and the danger of their occurrence is surely well known to those physicians in whose presence they have not yet occurred. It is unfortunate, as LeeRoy and Sword¹ have written, that almost all inhalant anesthetic drugs used today will burn or explode; further, that they are always given with air or pure oxygen; and that these mixtures are confined in closed spaces in the anesthetic apparatus and in the patient's respiratory system. The various ethers, ethylene, and cyclopropane have been involved in numerous fires and explosions. Nitrous oxide has been exonerated only in the laboratory. It is stated to have been the sole anesthetizing agent in the instance of an explosion described in 1924.² The gas was reported to be a mixture of nitrous oxide and oxygen; the source of heat, the high frequency electrical cautery. On touching the patient with the electrode, an explosion took place in the gas mask and rubber tubes. It was theorized that "the explosion occurred by reason of the fact that some carbon or foreign substance had got into the nitrous oxide and oxygen gas being used." According to Luckhardt,³ a nitrous oxide-oxygen mixture can be ignited and thus exploded by a thermocautery. Herb,⁴ substituting nitrous oxide-oxygen for ethylene-oxygen, reported two explosions "with this gas" within a few

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weeks. Ether was present in the ether chamber of the gas machine when these explosions occurred; it became ignited "in one of the nitrous oxide-oxygen explosions." Wilson, in discussing an article by Blomfield,⁵ described two cases of fatal explosion in England associated with nitrous oxide anesthesia; a bronchoscope was used in one case, a flame reached the patient's mouth in the other. The explosion of a tank containing nitrous oxide was reported in 1929⁶; the tank was on the floor, disconnected from the machine, and its valve was being manipulated at the time of its explosion. It was assumed that the tank contained some ethylene, as the machine in the operating room on the occasion of the explosion was not equipped with a device rendering impossible the mixture of these gases; there was no further evidence for this assumption. The *British Medical Journal*⁷ referred, in 1935, to "explosion limits" of nitrous oxide, to the "ready ignition" of this gas, and warned that it was not to be regarded as inert. Livingstone, Shank, and Engel⁸ reported, in 1939, three so-called nitrous oxide-oxygen explosions, one in Missouri (urethral caruncle cauterization) and two in England (both during the use of a bronchoscope); they suspected the presence, in the apparatus, of ether or oil or, in the nitrous oxide, of carbon or "foreign substance." Greene⁹ reported, in 1941, an explosion of nitrous oxide-oxygen "plus unknown." Pinson¹⁰ reported "alleged explosions of chloroform vapour." Kretschmer¹¹ reported two explosions, in 1934, occurring during transurethral electroresection of the prostate under sacral anesthesia. He added, "Practically every urologist, during the course of fulguration treatment of bladder papillomas has at some time or another experienced small intravesical explosions." The explosive mixture in these cases, where no combustible gas has been administered, is hydrogen-oxygen, products of hydrolysis of water in the bladder by the action of the electric current.

HOW GREAT IS THE DANGER?

"The total number of ethylene fatalities," wrote Williams¹² in 1930, "has not been large. Were there no remedy it might even seem proper to continue its use in the manner and with the equipment hitherto employed." Henderson,¹³ writing in 1930, defended the anesthetic apparatus of the day, stating that explosions caused one death in about 100,000 anesthetics, and that, in comparison, other commoner hazards consequent on older methods of anesthesia were greatly reduced. He said that ether is responsible for more explosions or flares than ethylene and concluded: "Explosion is today the least of the hazards of anesthesia." "Respiratory complications and shock from improperly administered anesthetics," wrote Griffith in 1931,¹⁴ "cause a hundred times more deaths than all the explosions." One fatal anesthetic explosion receives widespread attention, the *Journal of the American Medical Association*¹⁵ declared editorially, while 100 deaths from postoperative pneumonia may go unpublished. Herb¹⁶ listed the reported explosions in 1933 as follows: ethylene, 20 explosions with 5 deaths; nitrous oxide-oxygen-ethylene, 2 deaths; nitrous oxide-oxygen-ether, 39 explosions with 5 deaths. She asserted that 20,000 anesthetics were given with no explosion, following the installation of a conductive grounded floor; she had reported,⁴ in 1925, 5 ethylene explosions in about one and one-half years at one hospital, occurring in what was later referred to as a few hundred anesthetics. Phillips,¹⁷ writing in 1936, believed that the danger of anesthetic explosions was great. With the advent of ethylene, wrote Guedel¹⁸ in 1937, "we became explosion conscious." An editorial⁶ of the *Journal of the American Medical Association* (1939) estimated the frequency of ether accidents

at about 100 a year. "Ether anesthesia," it said, "is too well established to be affected by explosions, which are usually not even reported." The Subcommittee of the American Society of Anesthetists on Fires and Explosions¹⁹ listed all reported explosions for the fifteen-year period from 1925 to 1939 as follows: ether-air, 23 explosions with 2 deaths; ether-oxygen, 10 explosions with 3 deaths; nitrous oxide-oxygen-ether, 19 explosions with 9 deaths; ethylene-oxygen, 16 explosions with 5 deaths; cyclopropane-oxygen, 9 explosions with 3 deaths; cases in the last two groups included those in which ether or other agents had been added. Woodbridge,²⁰ writing in 1939, suggested that the explosive risk was very small, in proportion to the other risks attending surgery and anesthesia, and that the dramatic nature of an explosion was largely responsible for the publicity and fear associated with this hazard. He asserted that the explosion rate was about 2 to 4 per 100,000 administrations; this was based on 64 explosions occurring in $2\frac{1}{3}$ million anesthetics, with 2 deaths. Pinson¹⁰ asserted that at least 100 ether explosions probably occur in England annually. Livingstone, Shank, and Engel⁶ offered, in 1939, the findings of 6 collections of anesthetic explosions. The first study was by Herb, who, they stated, reported (in 1930) 1,005,375 ethylene anesthetics, with 20 explosions and 5 deaths. The second study reported by them was that of Henderson, in which ethylene anesthetics at 288 hospitals resulted in 10 explosions and 1 death. Their third group of cases was reported by Cabot; 146,000 ethylene anesthetics given at 75 hospitals resulted in 1 explosion and 1 fire. Their fourth list was based on the reports of 58 surgeons, according to which more than 163,000 ethylene anesthetics resulted in 18 explosions and 1 death. The fifth group cited by these authors was that of Salzer who, in 1929, reported 425,000 ethylene anesthetics with 10 explosions and 1 death. The sixth collection offered by Livingstone and her colleagues was as follows: ether or ether-oxygen, 34 accidents; nitrous oxide-oxygen-ether, 14 explosions; ethylene-oxygen, 14 explosions; cyclopropane-oxygen, 11 explosions; oxygen, 9 accidents; nitrous oxide-oxygen, 3 explosions; there were 27 deaths in this last series. Horton²¹ stated, in 1941, that anesthetic explosions were rare. Greene⁹ reported, in 1941, a collection of 230 anesthetic fires and explosions.

Injuries to the patient usually include burns, rupture of the lungs, and trauma from flying metal and glass. Greene⁹ was able to report 3 cases of recovery from ruptured lungs.

ARE THE RISKS DIFFERENT FOR DIFFERENT COMBUSTIBLE AGENTS?

Luckhardt and Lewis,²² writing in 1923, in one of the earliest articles describing the anesthetic properties of ethylene and its use in man, warned of its inflammability and explosibility. Henderson¹³ stated, in 1930, that ether is responsible for more minor explosions or flares than ethylene, but that ethylene explosions are more violent. Luckhardt³ believed ethylene-oxygen mixtures to be no more dangerous from an explosive standpoint than ether-oxygen mixtures. The Council on Pharmacy and Chemistry of the American Medical Association reported,²³ in 1939, that it considered cyclopropane to have the same potential explosion hazard as ether and ethylene. Woodbridge²⁴ concluded from his study of $2\frac{1}{3}$ million anesthetics that ethylene, cyclopropane, and ether (given with oxygen or nitrous oxide) are equally dangerous from the explosive standpoint, and that drop ether is safer. Horton²¹ declared, in 1941, that the rarity of anesthetic explosions rendered statistics "inadequate to show whether one gas is relatively more dangerous than another, or whether there is an increasing fre-

quency of occurrence of anesthetic explosions." Greene²⁵ attributed the apparent safety of ether to "the relative harmlessness which is associated with the combustion of any anesthetic mixed with air."

SHOULD ANY GAS BE BANNED?

Griffith¹⁴ warned, in 1931, that going back to ether-oxygen or to nitrous oxide-ether-oxygen had without justification given several workers a feeling of security and had made them neglectful of the usual precautions to be taken when working with explosive mixtures. Woodbridge quoted Guedel, in 1939,²⁰ to the effect that prohibiting the use of ethylene or cyclopropane was ridiculous. Poe's opinion²⁶ on the banning of ethylene (1930), typical of most physician-anesthetists, is worth quoting: "To discard ethylene in anesthetic is like discarding the use of gasoline in transportation, because some persist in using a match to see if the tank is empty."

IS ETHER DANGEROUS?

That ether mixtures will explode has been pointed out by many investigators. That the likelihood and violence of such explosions are increased by the substitution of oxygen for air in ether mixtures has been stressed in many articles. Black²⁷ reported, in 1874, a relatively harmless ether fire initiated by the actual cautery used in removing a tumor of the neck; other ether fires and explosions very likely happened before this. An ether explosion was reported as early as 1892,²⁸ in England; ether upset near a fireplace became ignited and exploded, shaking the house, breaking windows, and demolishing the room. Brown²⁹ stated, in 1924, that nitrous oxide-oxygen-ether mixtures were as explosive as ethylene-oxygen mixtures. Writing in 1928, Lundy³⁰ declared that the flash points of ethylene and ether are about the same. Poe²⁶ warned, in 1930, of the danger of administering ether-oxygen by insufflation because of the great violence of ether-oxygen explosions, and, it is assumed, the likelihood of the occurrence of an explosion with this technique; at the same time, however, he recommended the practice of performing ethylene-oxygen anesthesia with nitrous oxide induction, a procedure regarded as dangerous by later writers. Guedel¹⁸ stated that the substitution of oxygen for air in ether anesthesia increased the speed of flame propagation into the lungs and heightened the violence of the explosion. Livingstone, Shank, and Engel⁸ have said that ether explosions have occurred during anesthetics in which this agent was given by the open-drop method, by motor-driven ether vaporizers, and by various machines in combination with oxygen; that the source of ignition has on different occasions been turning on an electric light, the laryngoscope, cautery (in one instance, during a hemorrhoidectomy), static spark, electric penlight, cigarette, diathermy electrode, motor blower, fulguration tip, operator's headlight, fluoroscope, suction motor, and the bronchoscope. In their discussion of nitrous oxide-oxygen-ether mixtures, these authors have well said: "The very presence of this mixture in an apparatus, whether or not it is in use, is to be treated with great respect." Woodbridge, Horton, and Connell³¹ warned, in 1939, that ethyl and vinyl ethers and ethyl chloride are explosive in air, oxygen, and nitrous oxide. Newcomer³² emphasized, in 1940, the explosiveness of ether-oxygen mixtures, adding that they ignite at even lower temperatures than cyclopropane-oxygen. "The ether explosion hazard," wrote Morrill³³ in 1941, "very closely approximates that for ethylene." Ether-air mixtures, Greene⁹ stated, have produced fatal explosions but they tend very little to propagate "a wave of flame or pressure into and down the respiratory tract"; ether-oxygen, however, with

or without nitrous oxide, has as great a tendency to do this as has ethylene-oxygen or cyclopropane-oxygen. Morgan³⁴ stated, in 1931, that while ignition temperatures of hydrogen, carbon monoxide, and methane are about 500° C., ether vapor will ignite at about 190° C., and that "liquid ether when contaminated by impurities may ignite at a temperature as low as that of boiling water." "From time to time," wrote Featherstone³⁵ in 1931, "I hear of a minor 'pop' having occurred when a small lighted electric bulb has been inserted into the mouth during ether-air anesthesia." Commenting editorially on an ether explosion in 1903, the *Lancet*³⁶ stated that "it is well known that a mixture of ether vapour and atmospheric air is highly explosive."

HOW DOES AN EXPLOSION OCCUR?

The conditions necessary for an explosion are, as Rovenstine³⁷ has well stated them, "an inflammable gas vapor or other substance; oxygen, either pure or in the air, or a gas or other substance that provides oxygen, such as nitrous oxide; and a source of ignition." It is, therefore, easily understood that attempts to solve the problem of anesthetic explosions would be directed toward the elimination of each of these three conditions. Two other types of explosion, due to (a) pressure and (b) the presence of a spontaneously combustible mixture, will be referred to later.

IGNITION

The sources of heat serving to ignite combustible mixtures are numerous, as many investigators have listed them. The dangers of the open flame and cigarette have long been recognized. The hazard of the actual cautery has long been known and, more recently, the dangers of the electric cautery, diathermy, and x-ray apparatus have come into widespread knowledge. Greene⁹ reported, in 1941, a collection of 230 anesthetic fires and explosions. Of these, x-ray apparatus was involved in 10 cases, cautery apparatus in 57 cases, diathermy apparatus in 20 cases, suction-pressure machines in 59 cases, endoscopic apparatus in 5 cases, and static electricity in 63 cases. The ignition point of a combustible gas, according to Pinson,¹⁰ is the temperature at which it "fires." "The term 'flash point,' refers to a liquid," he wrote, "being that temperature at which it gives off inflammable vapour." Adriani³⁸ defined flash point as the "lowest temperature at which vapor of a liquid may be ignited"; kindling temperature as the "lowest temperature at which a combustible mixture ignites and continues to burn per se." According to Cooper,³⁹ the flash point, which indicates the ability of a liquid to form explosive mixtures, is the temperature to which the liquid must be heated to produce a flash or flame when a small flame is passed across the liquid's surface. Ethyl and vinyl ethers, he pointed out, have very low flash points and can thus form explosive mixtures in oxygen or in air at temperatures below 0° F. A sufficiently large portion of a gaseous mixture, he wrote, must be heated to its ignition temperature, that temperature at which rapid combustion becomes independent of external supplies of heat, and that temperature must be maintained until ignition occurs in order that the mixture be exploded. Any combustible, he added, when mixed with oxygen will ignite at a lower temperature than when mixed with air; the difference is not usually great but it amounts to more than 100° C. for ether. According to Blomfield,⁵ the rapid ignition point of ethylene in oxygen is 604° C., "a temperature at which a solid body is just visibly red in a dark room"; proportions of the gases were not given. He further stated that (a) raising the pressure caused a lowering of the ignition point; (b) reducing "the presence

of the oxygen" produced an initial rise in the ignition point, then a lowering of this temperature, and finally a noncombustible mixture; (c) the ignition point of ethylene is lower in nitrous oxide than in oxygen. Dixon⁴⁰ warned, in 1926, of the danger in bringing a heated body in contact with an ether-oxygen mixture. "That the heated body is not visible red-hot," he wrote, "is no guarantee of safety; the danger point begins at least 300° C. below visible redness." Pinson¹⁰ stated, in 1930, that visible red heat is necessary to ignite an ether-air mixture. Ether-oxygen mixtures can be ignited, according to Cooper,³⁹ at 184° C., a temperature well below a visible red heat.

Greene⁹ stated, in 1941, that "most anesthetics by insufflation today are still being administered in the presence of serious, obvious and preventable sources of ignition"; he called attention to the large number of accidents (more fires than explosions) and to the small number of injuries and recommended (a) mercury switches, (b) sealed motors, (c) grounding the metal cabinet, and (d) high, locking wall outlets.

ELECTRICAL EQUIPMENT

The existence, location, and condition of such obvious sources of ignition as outlets, switches, wires, terminals, cautery, high frequency apparatus, and lamps are usually obvious and should be known by the entire operating room personnel. Phillips¹⁷ listed, in 1936, the following as the usual electric circuits and equipments that are dangerous in the operating room: lights and light fixtures, receptacles and attachment plugs, all switches, all rheostats and adjustable transformers, cords to portable and semiportable equipments (in fact, all exposed cords and wires), electric sterilizers, cauteries, electrically illuminated lights, diathermy, fulguration, high frequency, x-ray, and fluoroscopic equipment, electric motors (suction devices, bone saws), electrocardiograph, telephones, buzzers, telephone magneto-ringers. He pointed out three dangerous features of the electric cautery: (a) the heat deliberately generated, (b) the frequent sparking of the rheostat or transformer used to regulate the temperature, and (c) the possibility of breaking or separation of cords and terminals with arc formation. All electrical circuits in the operating room, Tovell and Friend⁴¹ wrote, in 1942, should be supplied by insulated transformers outside the room; the three-wire type of wiring should be used, they stated, the third wire serving to ground all housings. They emphasized the importance of safety type switches, receptacles, plugs, motors, and lighting fixtures.

Greene⁹ collected five combustions due to electrically lighted instruments, as the bronchoscope, laryngoscope, and pocket flashlight; these were attributed to faulty contacts, poor insulation, breaking of bulbs, and short circuits. He recommended solid glass bulbs, low voltages, and properly functioning apparatus.

THE STATIC SPARK

Static spark is a more elusive source of ignition. Its location is not fixed, its occurrence cannot be predicted, and the conditions necessary for its creation are not perfectly understood by all workers.

The manner of formation of electrostatic charges has been described by many authors. Separation of insulating materials such as fabrics and rubber sheets, percussion, and friction (as in the breathing bag) are known to be common generators of static charges.

Horton⁵⁵ stated, in 1939, that a person wearing cotton garments could acquire a potential of more than 400 volts by moving about on a cushioned steel;

wearing street clothes increased the potential to several times this figure. He found fabrics to be responsible for most of the other sources of potential in the operating room. Merely draping the patient gave him a potential of about 40 volts to ground; inserting pads between the sterile sheet and the neck raised the patient's potential 150 volts; removing the instrument tray stand from the foot of the table gave the patient a potential of 50 volts. Farrand⁴² asserted, in 1939, that a nurse "may in the course of an errand pick up a charge of several thousand volts"; he showed that manipulation of and breathing into the breathing bag generated from 200 to 1,000 volts, that turning a rubber-covered pad on an operating table generated about 6,200 volts.

In considering electrostatic charges, Newcomer⁴³ pointed out the fact that the capacity of the storing body, as well as its potential, is important, and that the potential does not alone indicate, under given conditions, whether or not a spark will incite an explosion.

According to Finch,⁴⁴ currents carried by the discharge produced at the breaking of an electric current are usually less than 1 amp. The rate of energy dissipation is low, he added, but the total amount of energy may be large if the discharge is prolonged over a considerable fraction of a second. The rate of energy dissipation in the case of static spark, he stated, is enormous, but is maintained for only a fraction of a millionth of a second. Several investigators, according to E. T. Jones,⁴⁵ have been of the opinion that spark ignition of an inflammable gas mixture was due, not to the heat developed, but to the current itself, or its ionizing effect, in the gas. Jones showed, however, that the ordinary spark is a better igniter than the condenser spark (in which the current crossing the spark gap is greater) and inclined to the thermal theory of spark ignition, that ignition depends on "the volume of the gas which the spark can by its own heat raise to the ignition temperature."

The electrical effect of the passage of gas through breathing tubes has been commented upon by many writers. Phillips¹⁷ asserted that the flow of dry gases through rubber tubing will produce static charges. Luckhardt,³ writing in 1924 of the possibilities of explosion, from ignition by a static spark, of ethylene-oxygen mixtures in the tubing, considered the mechanism of such spark formation to be largely or entirely the "development of static electricity as the result of the long-continued flow of an ethylene-oxygen mixture in the tubing." Williams¹² asserted that passage of dry gases through rubber tubing which is dusty or contains metallic powder from valve wear may create charges of several thousand volts in a few seconds. He further contended, in 1930, that the inside of the breathing tubes and bag is not kept moistened by the water vapor in the patient's exhaled breath; the compressed gases, he maintained, are made dry and adsorb water "with great avidity." According to Brown,²⁹ static sparks formed by a charge generated by the passing of a gas under pressure through a narrow orifice (the only method of spark formation in the operating room considered in his article) are not likely to produce an explosion. Sise⁴⁶ believed that ethylene flowing over rubber could generate a static charge. Wardell⁴⁷ asserted that the passage of gas may create static charges, if some particles of dust or liquid are present. The matter of liquid particles has been mentioned by several writers, and it is food for thought that their presence has been considered a factor in the production of static and at the same time a method of dispersing such charges. Rayner⁴⁸ advised, in 1938, blowing off a little oxygen before starting a new tank, to remove water or dust particles, which might cause the formation of static during the high rate of flow of the gas. McDiarmid⁴⁹

quoted Kelvin to the effect that bubbling air through water causes the air to acquire a negative electrostatic charge. Knowing that the interfriktion of solids produces a measurable electrical charge, she investigated the possibility of the production of electricity by the friction of gases on solids. Air was passed through tubes constructed of different materials (insulators: glass, quartz, ebonite; metals: iron, copper, brass, aluminum; rubber was not tested) and of different bores and lengths. She found that (a) charges were developed on the air and on the tubes; (b) the charge on the air was opposite in sign to that on the tubes; (c) the signs of the charges on the tubes were positive for some insulators and for some metals and negative for other insulators and other metals; (d) the charge developed on the air was directly proportional to the length of the tube; (e) electrification increased with the speed of flow; (f) wider tubes produced greater charges, as they permitted a greater speed of flow; (g) the greatest deflection of the electrometer needle, calibrated at 300 to 600 mm. per volt, was 950 mm., which would thus correspond to a charge of about $1\frac{1}{2}$ to 3 volts; this was produced by a $5\frac{1}{4}$ second flow through a 10 mm. bore glass tube 78 cm. long, which would thus correspond to a rate of flow of about 695 c.c. per minute; the potential to which a metal container was raised, into which the air was conducted, was of the order of magnitude of 1 volt. No gas other than air was tested. It would thus seem that the charges created in this manner are too small to be significant in the etiology of explosions of anesthetic gases by static spark.

IS THE MACHINE THE OFFENDER IN STATIC FORMATION?

That a good part of the danger of electrostatic charge formation arises from the anesthesia apparatus itself has been contended by several authors. The theory of static charge formation by the movement of gas through the anesthesia apparatus has already been discussed.^{3, 12, 17, 29, 46-49} Phillips¹⁷ stated definitely that the anesthetic machine, with its breathing bag, tubes, and mask, constituted "the greatest single explosion hazard." Apart from the newest machines, equipped with conductive rubber throughout, Greene⁹ was unable to find, in 1941, any apparatus "which can claim a real superiority with respect to the hazard of static production within the apparatus." He concluded, from a study of 63 static explosions, that the greatest danger lay in the anesthesia apparatus itself, with its breathing bag, tubes, and mask. Other investigators have felt, however, that little or no danger of static spark formation is created by the anesthesia apparatus itself. Connell,⁵⁰ representing the manufacturer of anesthesia apparatus, maintained, in 1939, that most static in the operating room is created by the unit including the patient, drapes, and attendants; less static, he felt, is generated by the anesthetist, and least by the apparatus. Used properly, the anesthesia machine, according to Horton,²¹ does not contribute to the cause of ignition; he warned, however, of the danger inherent in the practice of removing the breathing bag during anesthesia and in the use of metal collars on breathing bags. Rayner⁴⁸ was of the opinion (1938) that charges responsible for explosions were developed outside the anesthetic apparatus. Lee-Roy and Sword¹ declared, in 1942, that "the possibilities of fire or explosion originating within the anesthesia apparatus and the patient's respiratory tract are remote for two reasons. Firstly, we do not always have a mixture that is easily ignited. Secondly, there is little if any possibility of ignition from within."

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Greene's series⁹ of 230 fires and explosions, where it was reported to have been the igniting agent in 63 of the accidents. An analysis of these explosions showed that static explosions occurring during anesthesia with ether-oxygen, ethylene-oxygen, or cyclopropane-oxygen almost invariably result in an injury to the patient, and that static ether-oxygen explosions often kill him.

EFFORTS TO REDUCE THE DANGER OF STATIC SPARK

As has been shown by many investigators, the presence of water vapor in the atmosphere serves to dissipate electrostatic charges on all bodies within its reach; the air or gas mixture is rendered somewhat conductive and charges tend to leak away from bodies on which they are generated, so that spark formation becomes less frequent or may not occur at all. Griffith¹⁴ believed, as he wrote in 1931, that a static spark could not be produced in an atmosphere with a relative humidity of 54 per cent or more. He considered humidification to be the most effective method of eliminating static, and with it most of the anesthetic danger. Henderson¹³ recommended, in 1930, a high relative humidity in the atmosphere of the operating room and moistening the gases inside the machine. Woodbridge, Horton, and Connell¹¹ employed other precautionary measures, but stressed the importance of humidification in the operating room. Wiggin⁵¹ recommended humidification above 65 per cent. Sise,⁵² in 1933, regarded humidification as the best safeguard against static spark.

Rovenstine,³⁷ writing in 1939, favored the practice of humidification. According to Cooper,³⁹ a relative humidity of 60 per cent or more in the operating room will eliminate the formation of static charges except within the gas machine itself; rinsing tubes, mask, and bag before anesthesia will increase the humidity inside the apparatus, he wrote. Draper,⁵³ too, conformed to the theory that moisture in the atmosphere dissipates static charges. Of 63 static explosions, Greene⁹ found the relative humidity to be 60 per cent or more in 2 cases, 54 to 55 per cent in 3 cases, less than 50 per cent in 32 cases, not reported in 26 cases; of the 46 cases in which the seasonal incidence was given, only 2 occurred in the summer (when the humidity is high). He could find no reported static explosion in Australia and only one in England (the humidity in this case had been artificially established at a low level). He felt that humidification would not prevent all static formation, but that it should, nevertheless, be used. Phillips¹⁷ asserted that humidification dissipates charges more efficiently than wiring, since the water reaches all surfaces.

The effect of humidity on the incidence of static explosions is borne out by Petavel's assertion⁵⁴ that the risk of static explosions is not great in England, where the atmosphere is not very dry; static explosions are rare in Australia and in England, where only one such accident has been reported. As Rayner⁴⁸ has well put it, "very cold, dry weather produces the worst conditions, for the outside air contains little moisture, and when it is heated the relative humidity becomes low."

The practice of humidification has not been without its opponents, however. Newcomer,³² writing in 1940, did not believe that humidification would guard against static spark. The disadvantages associated with the maintenance of a high humidity, as Herb¹⁶ has stated, are twofold: the constant attention necessary for the carrying out of such a program with the dangerous possibility of an unobserved fall in the relative humidity, and the discomfort experienced by an operating room personnel working in a high humidity in a warm room. Finch,⁴⁴ in 1935, considered humidification "not likely to be of much use." Fol-

become insulated after a few steps on a powdered surface. Horton²¹ favored grounding the conductive floor, since, the object of intercoupling being the maintenance of everything in the room at one potential, and it being necessary that some objects be at ground potential, all objects should be at ground potential. He described four types of conductive flooring: (a) the embodying of metal strips in a terrazzo or tile floor; (b) conductive rubber flooring; (c) a laminated floor, consisting of a layer of thin porous tiles covering a thickness of cement, in whose upper surface a copper screen is incorporated; (d) calcium chloride treated tile or terrazzo floor. Sparks may be struck from tile, he pointed out, by iron or steel which may be present in shoes or metal furniture. Shoe soles of ordinary rubber Horton stated, are dangerous; the resistance of leather may vary from 10,000 ohms to 10 megohms; conductive rubber is ideal for this purpose. Furniture in the operating room, he continued, should make contact with the floor through casters, feet, or crutch tips embodying conductive rubber or bronze (sparkless) drag chains. He wrote that surgeons' platforms, being insulators, are dangerous and should be coupled to the floor by feet of metal or conductive rubber. The patient should be directly connected to the table, for, as he warned, "in spite of all the conductive flooring and drag chains which may have been installed, the patient lying on the customary (operating table) pad is as completely isolated, electrically, as though he had been levitated." LeeRoy and Sword¹ suggested, in 1942, that charges may be built up too large for rapid dissipation to ground or intercoupled system, by the moving about in the operating room of charged bodies, and stressed the importance of the slogan: "Stand clear of anesthetic apparatus."

It is well known that substances differ widely in their ability to generate electrostatic charges. Horton²¹ advised, in 1941, that removing a fabric case from a rubber pillow be prohibited in the operating room or in any room in which anesthesia apparatus is kept. The danger of static spark is due almost entirely, he wrote, to the presence of rubber and fabrics in the operating room. He recommended that the use of wool, silk, and silk substitutes (excepting undergarments) be prohibited. Rubber gloves and silk stockings, he felt, are not very dangerous as they maintain close contact with the body of the wearer. Woodbridge, Horton, and Connell²¹ warned, in 1939, of the danger of having a cushion on the anesthetist's stool.

The use of conductive rubber throughout the anesthesia apparatus to render the machine conductive throughout, as well as on the furniture feet and shoe soles, has been recommended by many writers. Henderson¹³ advocated the use of conductive rubber in 1930. Farrand⁴² showed, in 1939, that the use of grounded conductive rubber prevented the accumulation of any readable potential on a breathing bag. Connell⁵⁰ felt, in 1939, that using conductive rubber would safeguard the apparatus as a generator of static spark. Newcomer⁴³ recommended, in 1940, the construction of a conductive rubber mat to be placed under the operating unit, the wearing of conductive rubber soles, and the use of conductive rubber in the anesthesia apparatus.

Wetting the various nonconductive or rubber parts of the anesthesia apparatus in an attempt to render them more conductive has been suggested by many authors. Connell⁵⁰ advised, in 1939, washing rubber tubes and bag with a calcium chloride solution to render the rubber conductive. Woodbridge, Horton, and Connell,²¹ in 1939, suggested the value of wetting rubber parts before use. Horton²¹ recommended, in 1941, rinsing all rubber parts used in anesthesia, with the exception of those touching the patient's or anesthetist's body, with a 2 per cent solution of calcium chloride.

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lowing the occurrence of at least one explosion believed due to electrostatic discharge in an atmosphere whose relative humidity was 65 per cent, Horton⁵⁵ showed, in 1939, by means of electrostatic potential measurements and by the production of actual sparks, that a relative humidity of 65 per cent does not fully protect against electrostatic sparks. Connell⁵⁰ expressed the opinion, in 1939, that the danger of static spark cannot be entirely eliminated by increasing room humidity; he called attention to the formation of lightning "in the wet air of thunderheads by the violence of gusts and water droplets." He agreed, however, that high humidity is of value and declared that the water content is raised after three breaths in a closed circuit, and that the circuit is drenched within one minute. The importance of the carbon dioxide content of the atmosphere in rendering the air more conductive by raising its electrolyte concentration was stressed by Tovell and Friend,⁴¹ who dispelled some of the confusion regarding relative humidity values. They stated that a relative humidity of 30 per cent may be effective where there is an excess of carbon dioxide and that a relative humidity of 65 per cent may fail to prevent the accumulation of static in the absence of carbon dioxide. The effect of increased atmospheric humidity in lowering the static danger by increasing the conductivity of the air would thus seem to depend on the electrolyte (chiefly carbon dioxide) content of the water vapor in the air. Others have attempted to correlate the efficacy of humidification with the voltage of the charge stored or dissipated.

Grounding or earthing has been and is employed by many anesthetists in an attempt to remove quickly any static electricity that may be discharged onto the patient, the operating table, or the anesthetic apparatus. Brown²⁹ advised, in 1924, grounding the cylinder or mask. Herb⁴ recommended, in 1925, the use of a grounded conducting floor, to which all tables, stands, and apparatus are grounded. Livingstone⁵⁶ advised, in 1930, that the operating table and anesthetic apparatus be grounded; to make the apparatus entirely conductive she recommended the use of spiral wire around the breathing tubes and wire mesh around the breathing bag. Newcomer³² recommended, in 1940, grounding of the patient, together with the use of intercoupling. Lewis and Boehm⁵⁷ stated, in 1925, that grounding the anesthetic apparatus, patient, anesthetist, and operating table would eliminate the danger of static spark. Phillips¹⁷ felt that grounding increases the energy of a spark received from a visitor and heightens the danger of a short circuit to the patient; he stated that "the proper evidence on the whole is against the grounding method." Henderson,¹³ in 1930, condemned the practice of grounding the anesthetic apparatus, maintaining that the protection was minimal and that the danger of short circuit from the electrical illuminating current was increased. Griffith¹⁴ declared, in 1931, that grounding did not protect against static. Rovenstine,²⁷ in 1939, did not employ grounding. Waters' technique,⁵⁸ as described by him in 1943, did not include grounding. Draper⁵³ favored (1928) grounding all bodies in the danger zone.

Artificially ventilating the operating room has been recommended by several writers; Cheney,⁵⁹ in 1929, favored the use of a ventilating device to remove all escaping ethylene mixtures from the operating room. This practice probably owed its popularity largely to the high content of anesthetic gas in the operating room atmosphere before the widespread use of the carbon dioxide-absorption rebreathing technique, popularized by Waters. Phillips¹⁷ recommended, in 1936, the use of ventilation. Newcomer³² warned, in 1940, of the danger of air conditioning; this practice, he stated, removes from the operating room atmos-

phere much of the carbon dioxide, the electrolyte that plays a large part in making air conductive.

The electrically connecting together of the various parts of the surgery-anesthesia unit has been recommended by many investigators, on the basis that these separate components are thus joined to form one electrostatic body, so that static sparks cannot pass from one object or person to another so coupled.

Lewis and Boehm⁵⁷ stated, in 1925, that grounding the anesthetic apparatus, patient, anesthetist, and operating table would eliminate the danger of static spark. All individuals and objects concerned, therefore, were, in addition to being grounded, intercoupled, with a minimum of resistance. Herb⁴ recommended, in 1925, the use of a grounded conducting floor, to which all tables, stands, and apparatus are connected; this, too, achieves direct intercoupling. Draper⁵³ also favored (1928) grounding all objects in the hazardous area, so as to include direct intercoupling. He used galvanized iron mats, that could be rolled up and were inexpensive; intercoupling was thus without high resistance and was associated with an attempt to render the anesthesia apparatus conductive by the use of wires inside the breathing tubes. Phillips¹⁷ called attention, in 1936, to the danger associated with spiral wire used in tubing: the possibility of breaking of the wire with spark formation where the presence of an explosive mixture is very likely. Waters,⁵⁸ in 1943, did not include metallic intercoupling in his reported technique, but advised continuous contact between anesthetist and patient. Horton⁵⁵ advocated, in 1939, the use of intercoupling to reduce the hazard of explosion from electrostatic discharge. The chief objections to intercoupling were met by using conductors having high resistance. These objections were due to the increased hazard from electrical shock, in the case of an accidental connection between the patient and the lighting circuit, and the increased energy which would be associated with any electrostatic spark from a body not a part of the intercoupled system. A resistance of 100,000 ohms, he found, will limit the current resulting from contact with the lighting circuit to about 1 per cent of the amperage necessary to constitute a danger. "A conductor having a resistance of one megohm," he wrote, "will equalize any charge which might produce a sparking potential as rapidly as it can be established." Woodbridge, Horton, and Connell,³¹ included in their published technique, in 1939, the use of resistance intercoupling, as did Wiggin⁵¹ in 1940.

In 1941, Horton²¹ again recommended the practice of high resistance intercoupling; he stated further, at this time, that grounding of the intercoupled system was beneficial. An estimate of the efficiency of the high resistance intercoupler in actual use was given by this author, who wrote, in 1941, the following: "Experience during the past year or more, in a large number of operating rooms, has disclosed nothing to indicate that the intercoupler fails to function exactly as intended. There have been no reports of discharges of sparks of the type it was designed to eliminate. There have been no reports of any fatal explosion during anesthetics protected by it. In fact, of 19 explosions during the 1939-1940 season, only one occurred in the presence of an intercoupler. This particular explosion is believed to have resulted from a spark of the type . . . against which the intercoupler is known to offer no protection." Referring again to the advisability of grounding the intercoupled group, he wrote: "As a more permanent and exclusive method of intercoupling, an electrically conductive floor is ideal." Many writers have indicated that the floor and the air are, if rendered conductive, universal intercouplers, equalizing potentials on all objects in contact with them. It has been shown, however, that even conductive rubber soles

become insulated after a few steps on a powdered surface. Horton²¹ favored grounding the conductive floor, since, the object of intercoupling being the maintenance of everything in the room at one potential, and it being necessary that some objects be at ground potential, all objects should be at ground potential. He described four types of conductive flooring: (a) the embodying of metal strips in a terrazzo or tile floor; (b) conductive rubber flooring; (c) a laminated floor, consisting of a layer of thin porous tiles covering a thickness of cement, in whose upper surface a copper screen is incorporated; (d) calcium chloride treated tile or terrazzo floor. Sparks may be struck from tile, he pointed out, by iron or steel which may be present in shoes or metal furniture. Shoe soles of ordinary rubber, Horton stated, are dangerous; the resistance of leather may vary from 10,000 ohms to 10 megohms; conductive rubber is ideal for this purpose. Furniture in the operating room, he continued, should make contact with the floor through casters, feet, or crutch tips embodying conductive rubber or bronze (sparkless) drag chains. He wrote that surgeons' platforms, being insulators, are dangerous and should be coupled to the floor by feet of metal or conductive rubber. The patient should be directly connected to the table, for, as he warned, "in spite of all the conductive flooring and drag chains which may have been installed, the patient lying on the customary (operating table) pad is as completely isolated, electrically, as though he had been levitated." LeeRoy and Sword¹ suggested, in 1942, that charges may be built up too large for rapid dissipation to ground or intercoupled system, by the moving about in the operating room of charged bodies, and stressed the importance of the slogan: "Stand clear of anesthetic apparatus."

It is well known that substances differ widely in their ability to generate electrostatic charges. Horton²¹ advised, in 1941, that removing a fabric case from a rubber pillow be prohibited in the operating room or in any room in which anesthesia apparatus is kept. The danger of static spark is due almost entirely, he wrote, to the presence of rubber and fabrics in the operating room. He recommended that the use of wool, silk, and silk substitutes (excepting undergarments) be prohibited. Rubber gloves and silk stockings, he felt, are not very dangerous as they maintain close contact with the body of the wearer. Woodbridge, Horton, and Connell³¹ warned, in 1939, of the danger of having a cushion on the anesthetist's stool.

The use of conductive rubber throughout the anesthesia apparatus to render the machine conductive throughout, as well as on the furniture feet and shoe soles, has been recommended by many writers. Henderson¹³ advocated the use of conductive rubber in 1930. Farrand⁴² showed, in 1939, that the use of grounded conductive rubber prevented the accumulation of any readable potential on a breathing bag. Connell⁵⁰ felt, in 1939, that using conductive rubber would safeguard the apparatus as a generator of static spark. New-comer⁴³ recommended, in 1940, the construction of a conductive rubber mat to be placed under the operating unit, the wearing of conductive rubber soles, and the use of conductive rubber in the anesthesia apparatus.

Wetting the various nonconductive or rubber parts of the anesthesia apparatus in an attempt to render them more conductive has been suggested by many authors. Connell⁵⁰ advised, in 1939, washing rubber tubes and bag with a calcium chloride solution to render the rubber conductive. Woodbridge, Horton, and Connell,³¹ in 1939, suggested the value of wetting rubber parts before use. Horton²¹ recommended, in 1941, rinsing all rubber parts used in anesthesia, with the exception of those touching the patient's or anesthetist's body, with a 2 per cent solution of calcium chloride.

Slocum and Finvold⁶⁰ stated, in 1944, that ionization of the air causes the atmosphere to become a low-grade conductor, with subsequent equalization of electrostatic charges on all objects within the area of ionization. They had determined that a minimum of 1,375 volts was required to explode a 25 per cent concentration of cyclopropane in oxygen; they set out to ionize the air to such an extent that the potentials of no bodies in the area concerned could differ by this amount. They investigated eight methods of ionizing air: (a) shielded open flame, (b) corona discharge, (c) ultraviolet light, (d) ion generator, (e) radioactive paint, (f) roentgen rays, (g) grenz rays, (h) radium emanations. Of these, the use of radium was the only method adaptable for use in the operating room which was safe and efficient. "At a distance of six feet," they wrote, "40 mc. of radon will decrease the static charges on all objects or persons to less than ignition potential within a few seconds. Working time of the operating room personnel who stay within a six-foot radius of 40 mc. of radon must be limited to eight hours." Woodbridge, Horton, and Connell³¹ had previously warned (1939) that the production of ozone must be guarded against when the air in the operating room is being ionized, as both ozone-ethylene and ozone-cyclopropane mixtures are spontaneously combustible.

According to Greene,⁹ ether-air is the only inflammable anesthetic that can be used safely in the absence of static precautions.

Several investigators have attempted to solve the problem of anesthetic explosions by avoiding the use of combustible mixtures. Nitrous oxide and pentothal, used separately or together, have been advocated by many as the drugs of choice in the presence of any obvious source of ignition. Greene⁶¹ advised, in 1941, that only noncombustible anesthetic agents be used in the presence of x-ray apparatus. "Our study" (the committee appointed, in 1937, by the American Society of Anesthetists to study the problem of anesthetic fires and explosions), he wrote again⁹ in 1941, "forces us to conclude with the bold statement: anesthetic fires and explosions ignited by diathermy, like those due to x-ray apparatus, are completely preventable only by the use of noncombustible anesthetic methods."

Attempts have been made by several writers to create mixtures of combustible gases, particularly cyclopropane, rich enough in cyclopropane and oxygen to be anesthetically potent and safe, yet rendered noncombustible by the addition of other gases. Jones, Kennedy, and Thomas⁶² found (1940) that dilution with inert gases had little effect on the lower limits of inflammability of cyclopropane in air or in oxygen, but had a marked effect on the upper limit. Three inert gases were tested: carbon dioxide, helium, and nitrogen. Carbon dioxide proved to be the most efficient flame quencher, but is physiologically too active to be used for this purpose. The flame quenching properties of nitrogen and helium are about the same. The flame quenching property of a gas, they stated, depends on its molecular heat capacity and on its thermal conductivity; helium's heat capacity is low, but its thermal conductivity is very high. It can be breathed with less effort than nitrogen, they pointed out, a distinct advantage when the oxygen content is lowered. According to Coward, Cooper, and Jacobs,⁷⁷ they stated, another advantage of using helium is the fact that mixtures of gases in which helium is present cannot be as easily ignited by electric discharge as can mixtures containing the same concentrations of other inert gases. While potent noninflammable mixtures can be thus created, they warned that adding air or oxygen would make them explosive, and that a leak might thus cause a combustion; the violently explosive mixtures, however, are avoided.

Jones and Thomas⁶³ offered, in 1941, a technique of administering anesthesia with such noncombustible cyclopropane-oxygen-helium mixtures. They stressed the importance of not flushing the patient with oxygen at the end of anesthesia, because of the danger of returning the mixture into the explosive range. It seems, however, that breathing room air would tend to achieve the same result. Griffith¹⁴ advised, in 1931, that carbon dioxide, being a fire extinguisher, be used to flush out all gas machines after use. Jones and Thomas⁶³ admitted certain difficulties encountered in their attempt to eliminate the explosive hazard by diluting the mixture with an inert gas, due to (a) the variable oxygen needs of different individuals, (b) the sudden change in all concentrations attending a leak, and (c) the difficulty attending the determining of the concentrations of oxygen in the apparatus. Writing in 1943, these same authors⁶⁴ maintained that the practice of adding nitrous oxide to ether-oxygen mixtures, in an attempt to render the mixture noncombustible, is harmful rather than advantageous, since, as they showed, the lower limit of inflammability of ether in oxygen is further lowered by the addition of nitrous oxide. They were unable to find, during the course of further experiments, any ether-nitrous oxide-oxygen mixtures that were both noninflammable and suitable for anesthetic purposes. Clinical experiments, in which samples of ether-nitrous oxide-oxygen mixtures being given by different anesthetists were tested, showed that almost all mixtures used were explosive. The addition of helium, they stated, is of no value in eliminating the explosive hazard of these mixtures. The explosiveness of ether-oxygen mixtures and the danger involved in adding nitrous oxide to ether-air and ether-oxygen mixtures were mentioned in an editorial of the *British Medical Journal* in 1936.⁶⁵ Haas, Hibshman, and Romberger⁶⁶ were able, in 1940, to produce cyclopropane mixtures that were nonexplosive and anesthetically potent, by adding air to cyclopropane-oxygen mixtures. The mixtures they arrived at were similar to those tested by Jones, Kennedy, and Thomas,⁶² who diluted cyclopropane-oxygen mixtures with helium; Haas and his colleagues used nitrogen instead of helium, and were able to do this by simply adding room air to the breathing bag by means of an attached bulb. They showed, by means of a flammability graph, that all such mixtures were nonexplosive if they contained no more than 20 per cent of cyclopropane or no more than 11½ per cent of oxygen; the graph showed, however, that mixtures richer in both cyclopropane and oxygen could be used without danger of explosion. Means of accurately creating such mixtures and devices for rapid analysis of the mixtures seemed to be desirable. Horton⁶⁷ stated, in 1941, that adding an inert gas or even an explosive gas to a mixture of another explosive gas and oxygen may result in a mixture that is anesthetic, nonexplosive, and with a sufficiently high oxygen content. He cited two mixtures: the first containing 20 per cent cyclopropane, 50 per cent ethylene, and 30 per cent oxygen, for deep anesthesia; the second containing 10 per cent cyclopropane, 65 per cent ethylene, and 25 per cent oxygen, for light anesthesia; in either of these mixtures is the dilution obtained by the use of an inert gas. Cooper³⁹ stated, in 1939, that oxygen concentrations must be reduced below 10 per cent to prevent explosions, so that the addition of inert gases to explosive mixtures to reduce the oxygen concentration to a point where explosions cannot occur would not be practicable. Greene,⁹ in 1941, drew attention to his being unable to find any static explosion of cyclopropane-air; there were two explosions, however, of cyclopropane-oxygen-helium mixtures. Lee-Roy and Sword,¹ in 1942, decried the practice of diluting the anesthetic gas mixture with inert gases; they considered it difficult to estimate the amounts of

anesthetic agent, oxygen, and inert gases to maintain a proper degree of narcosis, avoid hypoxia, and secure a nonexplosive mixture. Greene²⁵ spoke, in 1942, of the "relative harmlessness which is associated with the combustion of any anesthetic mixed with air."

At least one attempt has been made to protect the patient by shielding him from the explosion that may occur despite attention to ignition and to the inflammability of the mixture. Hornor and Gardinier,⁴⁸ working with ethylene (1928), were able to intercept explosions experimentally. They constructed a mask incorporating a cylinder containing (a) fine mesh screen wire, (b) a by-pass, and (c) a valve which was closed, automatically, by the force of the explosion, in about $\frac{1}{5000}$ of a second; they estimated the maximum rate of propagation of ethylene-oxygen explosions to be 2,500 meters or $1\frac{1}{2}$ miles per second. This device, obviously, could protect the patient only from an explosion originating in the machine.

Salzer⁶⁰ described, in 1927, a method of removing spent ethylene-oxygen mixtures from the operating room. Cheney,⁵⁹ in 1929, advocated the use of copper screens to prevent the propagation of ethylene explosions and the use of a ventilating device to remove all escaping ethylene mixtures from the operating room. The closed rebreathing technique, popularized by Waters, has, of course, done much to eliminate the possibility of escape of large amounts of explosive mixtures.

The matter of leaks has received considerable attention. Brown²⁰ stated, in 1924, that the possibility of explosion when ethylene was allowed to escape was "only in the remote realms of possibility." Tyler, in discussing an article by Woodbridge, Horton, and Connell,³¹ in 1939, attributed to Connell the statement that diffusion is so great that cyclopropane leaking at a rate of 4 L. a minute will not explode four or five inches from the leak. Connell asserted,⁵⁰ in 1939, that gas diffusion is sufficiently rapid to render difficult, experimentally, flash backs from open flame six inches from the spillway; in the case of liquid ether, however, flash backs can occur from several feet away. Knight⁷⁰ has been unable to obtain an explosive mixture at a distance of two inches from an open leak of 500 c.c. per minute of a known explosive mixture of cyclopropane-oxygen. Greene⁹ collected 10 cases in which ether, ethylene, and cyclopropane have been ignited more than twelve inches from the nearest leak, but could find no fatality caused by the presence of cautery or flame outside a twelve-inch radius surrounding the upper respiratory tract. In reviewing 57 fires and explosions caused by flame or cautery, he wrote, "all deaths—and all were patients—have been the result of a flame or cautery employed within a twelve-inch danger zone surrounding the upper respiratory tract." "Dr. Squibb," McCardie wrote,⁷¹ "has seen ether take fire at a measured distance of fifteen feet between the source of escaping vapour and the source of fire"; the direction of escaping vapor was not mentioned. Leaks of ethylene have inspired many comments on the fate of this gas, whose density approximates that of air, in the operating room atmosphere. Rovenstine³⁷ has quoted Waters to the effect that ethylene floats in strata, and that static explosions always occurred within the apparatus, not without. Guedel,¹⁸ Davis,⁷² and Sise⁴⁶ believed, too, that ethylene can float in combustible layers in an operating room. Brown,²⁹ Jones,⁷³ and Phillips¹⁷ stated, however, that ethylene diffuses rapidly because of its lightness, to subexplosive levels.

Wineland and Waters⁷⁴ showed that true diffusion of gases takes place through intact rubber. Ten liter bags filled with various gases lost, in forty-

eight hours, the following weights, approximately: oxygen, 0.32 Gm.; ethylene, 1.00 Gm.; carbon dioxide, 4.68 Gm.; nitrous oxide, 7.00 Gm. Starting weights, apparently inclusive of the bags, ranged from about 112 to 192 Gm. The diffusion into the bags of the various components of the room air does not seem to have been considered, despite the fact that on one occasion, one of the bags gained in weight; the order of diffusion rates would not appear to be affected, however, these rates do not seem great enough to contribute to the danger of explosion. Flagg,⁷⁵ in 1937, recommended the practice of aspirating, into a small rubber syringe, the atmosphere overlying the operative field where the cautery is to be used; the contents of the syringe are then blown into the flame of an alcohol lamp. The cautery is believed to be safe if no change occurs in the color of the flame.

That explosions can occur without ignition has long been recognized. Greene⁹ divided the cases of fire and explosion, due to the high pressure under which anesthetic gases are stored, into three groups: (a) the sudden release of pressure into insufficiently protected parts of the apparatus; (b) "the passage of oxygen at high speed over combustible material, such as oil or a leather washer"; (c) mixing nitrous oxide and ethylene under pressure. Spontaneously combustible ozone mixtures have been mentioned. Sise⁴⁶ stated that a mixture of ethylene and oxygen at high pressure may explode spontaneously.

The inflammability of the patient's breath has been discussed by many writers. Pinson asserted,¹⁰ in 1930, that air exhaled two or three minutes after the termination of an ether anesthesia contains too little ether vapor to ignite. Williams,¹² in 1930, and Livingstone and co-workers,⁸ in 1939, warned that the patient's breath may remain explosive for some time following an anesthesia, so that precautions even on return to the room or ward would be necessary. Guedel¹⁸ maintained, in 1937, that the breath is noninflammable six or eight minutes after the termination of cyclopropane anesthesia; Connell⁵⁰ stated, in 1939, that the patient's lungs and the gas apparatus can be made free of ignitable gas in approximately two minutes by using a high flow of a noncombustible mixture and emptying the breathing bag several times.

Although the closed, rebreathing technique has done much to lower the explosion hazard, Greene⁹ collected reports of 18 explosions occurring during anesthesia administered by this method; these were attributed to breaking the circuit, favoring static spark formation and liberation of an inflammable mixture.

WHAT IS BEING DONE?

The role of the manufacturer of anesthesia apparatus includes, according to Connell,⁵⁰ the reduction of the possibility of ignition from mixture of combustible gases under high compression by furnishing an individual reducing valve for each cylinder, the use of nonsparking metals, gas-tight connections, and the construction of a central spill valve (to direct the flow of discarded gases away from the operating table and electrical equipment).

Precautions to be taken by the anesthetist would include: (a) the avoidance of combustible agents in the presence of obvious hazards, such as the cautery;^{9, 17} (b) eliminating the practice of washing out patient and apparatus with oxygen following an anesthesia;^{12, 13, 76} (c) the use of caution in spilling gas; (d) the employment of the intercoupler^{21, 32, 51, 55, 57} or the maintaining of continuous contact by the anesthetist with patient and machine⁵⁸; (e) use of the rebreathing technique⁵⁸; (f) washing tubes, bags, and mask with water or

calcium chloride solution;^{21, 31, 50} (g) elimination of unnecessary, sudden movements by the anesthetist, and of unnecessary adjustments of the mask.

The duties of the hospital have been stated by various writers to include: (a) the installation of safe lights, switches, and electrical wiring (the three-wire system); (b) the maintenance of a high humidity in the operating room;^{13, 14, 37, 39, 47, 51} (c) the prohibition of wool, silk, and ordinary rubber; (d) the banning of visitors from the area surrounding the anesthetic apparatus¹; (e) banning of open flame, cigarettes, etc., from the operating room; and (f) the construction of a grounded, conductive floor.^{4, 21}

The following is a list of some of the devices and practices recommended in the articles reviewed.

1. Safety wiring (three-wire type)⁴¹
2. Switches
 - (a) mercury (vaporproof)¹⁶
 - (b) same, with pilot light
 - (c) outside operating room¹⁶
3. Elevated electric outlets
4. Grounding^{32, 56, 57}
5. Inter coupling
 - (a) complete^{46, 47, 57}
 - (b) resistance^{21, 31, 41, 55}
6. Ventilation
 - (a) alone⁵⁹
 - (b) with humidification¹⁴
7. Wire screens
8. Humidification^{13, 14, 17, 31, 37, 39, 47, 48, 51-54}
9. Banning of wool and silk²¹
10. Sparkproof motors⁹
11. Grounded floor plate^{16, 53}
12. Conductive flooring^{16, 21, 32, 41}
13. Conductive rubber^{41, 43}
14. Dilution of mixture
 - (a) with inert gas^{62, 63}
 - (b) with inflammable gas⁶⁷
15. Nonsparking metals^{21, 50}
16. Elimination of flame, cautery, smoking, x-ray, faulty instruments, etc., in the presence of a combustible gas^{9, 13}
17. Alertness⁹
18. Rebreathing technique^{8, 17, 31, 41, 70}
19. Intercepting valve⁶⁸
20. Keeping visitors away from apparatus¹
21. Large rooms, to prevent brushing of people against equipment and each other
22. Continuous contact with hand and mask before beginning and during anesthesia^{8, 58, 70}
23. Banning of ordinary rubber soles and metal shoe spikes²¹
24. Ionization of air⁶⁰
25. Rinsing tubes and mask
 - (a) with water^{31, 70}
 - (b) with calcium chloride solution³²

26. Washing floor with calcium chloride solution³²
27. Eliminating ordinary rubber in the operating room²¹
28. Washing out machine with carbon dioxide at end of anesthesia¹⁴
29. Wet flowmeters
30. Turning on cylinder valves slowly⁴⁸
31. Blowing off some oxygen when starting a new cylinder⁴⁸
32. Keeping nitrous oxide and ethylene on separate machines,⁵⁶ or if on same machine, never opening both cylinders at one time¹⁸
33. Avoidance of unnecessary movements by the anesthetist and of frequent adjustments of the mask
34. Endotracheal technique⁷⁰

WHAT DOES THE FUTURE HOLD?

Griffith¹⁴ cited, in 1931, Henderson's statement to the effect that the discovery of any new nonexplosive gases was unlikely, and that the solution lay in humidification rather than in a search for a noncombustible anesthetic gas. Jones and Thomas,⁶³ in 1941, expressed their belief that the solution to the explosion problem in anesthesia lies in avoiding the use of explosive mixtures, that "mixtures containing 20 per cent cyclopropane and 80 per cent oxygen, now commonly employed, are so violently explosive that their use should be discouraged."

It is significant that, despite the numerous precautions recommended and undoubtedly practiced in connection with the problems of explosions in anesthesia, Haas, Hibshman, and Romberger⁶⁶ could state, in 1940, that "there has been no apparent decrease in the number of explosions."

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CYCLOPROPANE—A PERSONAL EVALUATION

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I ANESTHETIZED the first patient with cyclopropane on Oct. 9, 1930. From then until Sept. 1, 1944, this gas has been used as the major agent to anesthetize about 25,000 patients at Wisconsin General Hospital. It has been used as the induction agent and as an adjuvant in many additional administrations. For all these, I have been personally responsible, although actual administration has been conducted by others of skills varying from that of the fourth-year medical student to that of my associates with years of experience in clinical anesthesia. My confreres in the departments of surgery, pharmacology, and physiology as well as in the department of anesthesia have co-operated in the study and evaluation of the advantages and disadvantages of this agent. Their experimental findings, clinical impressions, statistical evaluations, and personal conclusions as well as my own have been published at various times.¹⁻³⁰

I shall attempt to state my present personal impressions as to the value of cyclopropane in the anesthetist's armamentarium. This opinion will be based largely upon personal experience in the operating rooms, influenced by the experimental findings at the University of Wisconsin and elsewhere when these have been verified by clinical observation. A regrettable repetition of personal pronouns seems necessary in such a discussion. It will be taken for granted that the reader is familiar with our former publications and therefore only those present opinions will be emphasized which are at variance with those previously expressed.

POTENCY

Dosage, Concentration, Premedication.—Some of our former publications failed to give proper weight to an earlier finding; namely, that previous administration of morphine to dogs reduced by 12 per cent the concentration of cyclopropane required to produce a given amount of depression.³ The administration of morphine, barbituric acid derivatives, scopolamine, and atropine to normal persons convinced us that adequate "drying" and sedative effects could be secured with much smaller doses of these agents before anesthesia than we had been using.³¹⁻³³ With markedly less premedication (one-quarter to one-half the doses formerly used) higher concentrations of cyclopropane can be employed without encountering too great depression of respiration. The importance of this fact will appear later. The extreme potency of cyclopropane, plus the rapidity with which the concentration of such a gas can be built up in the blood and tissues,⁴ increases the technical danger of "over-running" the dosage past the optimum point of effect for satisfactory anesthesia and into the realm where essential physiologic functions (such as respiration) are depressed or abolished. Obviously, adequate ventilation of the alveolar spaces is essential if control of saturation and desaturation of the tissues is to be maintained.

Respiration and Abdominal Relaxation.—Certain muscles of the abdominal wall are, at least accessory, muscles of respiration. Fortunately, the function of breathing resists depression by anesthetic drugs. Otherwise embarrassment to the anesthetist during their administration would be even more frequent than it is. In another sense, however, this is unfortunate because the margin between flaccid relaxation during operations in the upper abdomen and total paralysis of all the muscles of respiration is very narrow. Many of the older inhalation agents in moderate dosage tend to increase the activity of the muscles of respiration. Cyclopropane lacks this quality. Hence, in the case of cyclopropane, the margin between the point of partial paralysis of respiratory muscles necessary for relaxation of the upper abdomen and respiratory arrest is narrower. Dosage of cyclopropane must, therefore, be increased with the greatest care in the approach to relaxation of the upper abdomen lest the desired concentration be exceeded, resulting in ventilation which is inadequate to produce further saturation or to maintain the relaxation that has already been secured. Obviously previous depression of respiration by other agents is undesirable. If the anesthetist does not possess the necessary patience, skill, and mechanical equipment to accomplish a gradual saturation to the point of adequate relaxation without too much effect on respiration, he must resort to other means. Either he must supplement the administration with another agent, as for example ether or procaine, or he must resort to the use of artificial means of ventilating the lungs, abandoning dependence upon natural breathing for the time being. The latter course (the control of respiration by the anesthetist) has, in my estimation unfortunately, come to be utilized all too frequently. It is true that relaxation can thus be improved. Controlled respiration has the further advantage of placing movements of the diaphragm and the lungs under the control of the anesthetist. He may then in certain cases coordinate these movements with the steps in technique of certain operations (for example, on the lung or diaphragm) in a manner to simplify the surgeon's work. In such cases, controlled respiration is amply justifiable. Artificial ventilation is always better than inadequate natural breathing. However, if I am forced to use controlled respiration with cyclopropane solely for

the purpose of securing proper muscular relaxation, I do so with an admission that I have failed in patience, skill, or mechanical control in the technique used. "Good anesthesia" ought not to deprive a patient of so essential a function without a very good reason.

EFFECTS ON THE CIRCULATORY SYSTEM

A decrease of pulse rate from 120 beats per minute to 70 was observed when cyclopropane was administered to the first patient in 1930. The rate returned to 120 after the cyclopropane had been discontinued. In nearly all the patients skillfully and deeply anesthetized since then, the pulse rate has been between 60 and 70. During our early studies, intentional overdose sufficient to stop respiration, was administered to both dogs and patients on a good many occasions. Although arrhythmia was produced on some occasions, the appearance of these animals and patients was rarely alarming. Two series of comparative electrocardiographic studies were then initiated,^{3, 7} one with dogs and one with patients. In order to eliminate the effect of inadequate ventilation (excess of carbon dioxide and deficiency of oxygen), controlled respiration was instituted in all these studies before doses had been reached which would decrease ventilation. Individual variability was found but the fact was established that a direct relation exists between the concentration of cyclopropane and the occurrence of arrhythmia. It was also established that the effects on cardiac rhythm are usually reversible as soon as the concentration in the tissues is decreased. These conclusions persist after reconsideration forced upon us by statements of other workers. Suggestions that adjuvant medication (ether, barbituric acid derivatives, procaine, etc.)^{19, 20, 34-36} or further saturation with cyclopropane³⁷ are proper practical means of eliminating arrhythmia have *not* received support from my clinical observation. It seems safer and wiser to avoid arrhythmia when possible by using a conservative approach to the lowest effective concentration and to treat arrhythmia, when it occurs, by prompt reduction in the concentration employed. We continue to use scopolamine but in smaller doses than formerly and for a different purpose. It may or may not provide some protection against arrhythmia.

The question arises as to whether cyclopropane should be administered to patients suffering from diseases of the circulatory system. Such patients tolerate poorly physiologic insult of any sort. The abnormal pressure relations created by respiratory obstruction, the effects of lack of oxygen, of extreme changes of position, of loss of fluid, and all the other hazards of operation and anesthesia are exaggerated in the presence of cardiac disease. Protection from errors of technique is doubly important for such patients whatever the agent used. I personally have not avoided the use of cyclopropane in the presence of circulatory disease. The clinical impression gained has been that such patients are not more susceptible to specific damage from the effect of this drug than are other patients with normal circulatory systems.

AUTONOMIC EFFECTS

Considerable evidence has accumulated in support of the belief that cyclopropane hyperactivates certain of the autonomic mechanisms.^{38, 39} Bronchial constriction has been observed. Certain occurrences during cyclopropane anesthesia have been explained as due to an oversensitive sinoaortic or vagal mechanism which has even caused cessation of breathing and of the heartbeat. Considerable thought has been devoted to an analysis of our own clinical ex-

perience in this regard. After eliminating the effects of medication with other drugs (opiates, barbiturates, and the atropine group), our present opinion is that variable hyperactivation of the autonomic reflexes may occur in some individuals during insufficiently profound anesthesia with cyclopropane and intensified by the agent. From a practical standpoint, three methods seem to have been useful for the prevention of such reactions:

1. Premedication with scopolamine or atropine. Scopolamine in moderate doses, I think, has been reasonably effective.

2. The administration of nitrous oxide anesthesia as an accompaniment of cyclopropane has appeared to have prophylactic value. When such a reflex has been elicited, a short period of reversion to nitrous oxide has on certain occasions seemed to relieve the condition, permitting a later return to cyclopropane anesthesia.

3. Rapid induction with nitrous oxide-oxygen and cyclopropane to second plane anesthesia in preference to a slow induction with cyclopropane in oxygen as a vehicle has seemed to decrease the occurrence of such reflexes. Hypoxia should, of course, be scrupulously avoided. If one can anticipate the application of a stimulus to such deep reflexes as those originating in the mediastinum or upper abdomen, I believe that he can produce profound enough anesthesia with cyclopropane to prevent the embarrassment.

THE RESPIRED ATMOSPHERE

Experience of many years in the administration of agents by inhalation supports the following general principle. For "normal" persons, the concentration of oxygen in the anesthetic atmosphere should resemble that to which they are accustomed. When the mechanism of the patient for the transport of oxygen is defective, excess of oxygen should be limited to that which will compensate adequately for the deficiency in transport. Any great excess of oxygen over the 20 per cent normally available tends to permit us to overlook inadequate ventilation. Such an excess interferes with transport of carbon dioxide and a "pink" patient may suffer from considerable physiologic embarrassment. The tendency to disturbance of acid-base balance in modern anesthesia is often due to attempts to keep a patient pink with added oxygen in the presence of depressed or obstructed breathing. Maintenance of atmospheres during anesthesia, at or near the normal content of oxygen, will help to prevent this mistake. Inadequate exchange or obstruction will thus result in the warnings (for example, changes in pulse rate, blood pressure, breathing, color, etc.), and the condition will more likely be corrected. Of course, if depression or obstruction of respiration cannot be remedied, atmosphere enriched with oxygen is preferable to persistent hypoxia. Such a procedure, however, often corrects only a part of the abnormality. When considerable enrichment of the respired atmosphere with oxygen has been deemed necessary during anesthesia, it has proved helpful to reduce the oxygen gradually as the end of operation approaches so that the reaction of the patient may be observed.

Carbon Dioxide Absorption Technique.—Since cyclopropane does not increase respiratory exchange, the importance of properly adjusted absorption technique is easily neglected. Saturated soda lime, excessive dead space between the patient and the soda lime and excessive depression with nonvolatile drugs are all dangers which, if overlooked, may result in serious physiologic disturbance. Unless the administrator is familiar with the physiologic basis of anesthesia, he will do well to use a technique other than carbon dioxide ab-

sorption and an agent other than cyclopropane. It ought always to be kept in mind that anesthetic apparatus, including that designed for carbon dioxide absorption, has usually been devised for use with normal adult individuals. In dealing with the very weak and ill and particularly when anesthetizing children, the dangers of this technique are intensified. Unless specially arranged equipment can be used in such cases, cyclopropane had better be administered by an open method if at all.

Effects of Hot Weather.—Since no new facts have been determined since our earlier reports, it remains important to appreciate the dangers inherent in the accumulation of heat and moisture in the closed atmosphere. The changes resulting, perhaps from one of these factors, appear to hypersensitize the patient to the effects of accumulated carbon dioxide. Contrary to the belief of some anesthetists, absorption technique rarely accomplishes complete removal of carbon dioxide from the inspired atmosphere. When anesthetizing a patient suffering from fever on a hot day, the slightest muscular twitching or other abnormality should be sufficient reason for abandoning "carbon dioxide absorption."

The Hazard of Fire and Explosion.—Not only does the use of excessive percentages of oxygen predispose to the occurrence of unphysiologic conditions, but it also produces an atmosphere which can be ignited with less heat. Although judicious use of absorption technique should eliminate the fire hazard, whatever the atmosphere contains, the less explosive the mixture the better. In the 25,000 administrations mentioned, ignition of cyclopropane has taken place only once when a bag and canister containing oxygen and cyclopropane were carelessly dropped to the floor.³⁰

SUMMARY

1. The relation of the potency of cyclopropane to the use of opiates, barbiturates, and atropine-like drugs has been discussed. Necessity for limiting the dose of agents which depress respiration in conjunction with cyclopropane has been stressed. The narrow margin between relaxation of the muscles of the upper abdominal wall and those of respiration has been mentioned.

2. The importance of skillful slow approach to maximum saturation when arriving at profound anesthesia for upper abdominal operations has been emphasized. If this fails, personal preference has been expressed for supplementation with intercostal block anesthesia, curare, or some other method rather than resorting to "controlled respiration" for the sole purpose of producing more profound anesthesia. Controlled respiration should, in my estimation, be reserved for occasions when such control, synchronized with the surgeon's maneuvers, facilitates operative technique. Resort to it will probably continue to be a temporary solution of unexpectedly difficult situations.

3. A decrease in pulse rate to between 60 and 70 has, in my hands, been the usual accompaniment of well-conducted cyclopropane anesthesia. A marked and sudden decrease from this rate to below 50 has been observed to precede a sudden tachycardia. Arrhythmia may be seen before, during, or after these changes. When marked bradycardia, tachycardia, or arrhythmia occurs, a circulatory emergency is present and instant rapid desaturation should be begun, by artificial respiration if necessary. Dependence upon the prophylactic value of adjuvants (ether, barbiturates, atropine, etc.) or the therapeutic value of increasing saturation with cyclopropane appears, in my experience, to be unreliable and dangerous.

4. During very light cyclopropane anesthesia, the autonomic reflexes in certain individuals are hyperactive. Rapid induction to second plane anesthesia and the use of nitrous oxide as a vehicle during induction have seemed to reduce the frequency of adduction of the vocal cords. Reflexes induced by surgical trauma can usually be prevented by sufficiently profound anesthesia when produced before the stimulus is applied. However, exceptions have been observed. Scopolamine and atropine and perhaps nitrous oxide may be useful prophylactically.

5. It has been suggested that anesthetic atmospheres should, as nearly as possible, resemble normal atmospheres. Substitutions should be made with the welfare of the patient in view and then only sufficient change ought to be made to accomplish the desired effect. If technical facility and familiarity with the signs of hypoxia are lacking, oxygen as a vehicle is safer.

6. Certain dangers inherent in the use of the carbon dioxide absorption technique have been pointed out.

7. My experience of nearly fifteen years with cyclopropane leaves me with the personal impression that this agent permits rapidity of control of the depth of anesthesia impossible with other inhalation agents. However, this very fact may result in unfortunate and disastrous results when ignorance or carelessness accompany the administration.

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PROLONGED ANESTHESIA

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AT THE University of Minnesota Hospitals, due to the established ways of referring patients to the hospitals and to the staff, and due to the system of selection of admissions, it has come about that a larger than average number of complicated or long surgical procedures are carried out. It is perhaps of interest to report 1,000 consecutive operations which required anesthesia of three hours' or more duration.

In June, 1942, Grimm¹ reported to the staff 454 such consecutive cases ending April 27, 1942, and one year later Smith² reported an additional 385 such cases in the following twelve months ending April 27, 1943. In this communication we have added the succeeding 161 cases to complete the 1,000 and have consolidated them. In Table I we have shown the number of each of the main groups of cases, the average ages in each group, and the average durations of anesthesia in each.

TABLE I

	AVERAGE AGE (YR.)	NUMBER OF CASES	AVERAGE DURATION HR. MIN.
Brain	39	129	4 33
Other neurosurgery	40	79	3 35
Chest	25	33	5 13
Gastrectomies	57	308	4 45
Other gastrointestinal	54	256	4 14
Miscellaneous	46	195	3 37
Total		1,000	

Table II shows the preoperative conditions of the patients and indicates to a large extent how well the patients are prepared for surgery. The figures of the three different collections are remarkably uniform but show a tendency toward an increase in the preoperative hemoglobin and plasma protein in all but the chest cases, in which there has been a decrease.

TABLE II. PREOPERATIVE CONDITIONS OF PATIENTS

	AGE (YR.)	PREOP. BLOOD PRESSURE		HB. (GM.)	PLASMA PROTEIN (GM.)
		SYST.	DIAST.		
Brain	39	168	78	13.16	6.35
Other neurosurgery	40	149	73	13.50	6.70
Chest	25	134	75	11.60	7.10
Gastrectomies	57	132	75	13.90	6.70
Other gastrointestinal	54	132	71	12.00	6.90
Miscellaneous	46	136	76	12.90	6.50

Table III shows the preoperative medication. Barbiturates were practically not used at all. In the first series of 454 cases more patients in each classification received codeine than morphine. About five years ago one or two of the surgical staff had had some bad results which were ascribed to

morphine so that morphine was interdicted in all brain cases, in all chest cases, and for all patients over 50 years of age. We still give no morphine in brain cases but other patients receive it in proportion to our judgment of their vigor, etc. Some who received codeine were so evidently undermedicated that they were also given morphine intravenously upon arrival in the operating room. In the earlier survey 60 per cent received atropine and 40 per cent received scopolamine. Since then almost 100 per cent have been given scopolamine, and we believe that it adds to the "don't care" composure of the patient and is more efficient in controlling secretions.

TABLE III. PREMEDICATION

	MOR- PHINE	CO- DEINE	ATRO- PINE	SCOPOLA- MINE	BARBIT- URATE
Brain	12	108	47	81	1
Other neurosurgery	43	30	11	59	
Chest	12	20	12	21	
Gastrectomies	304	79	73	204	
Other gastrointestinal	183	70	74	178	
Miscellaneous	166	15	32	160	6
Total	720	322	249	703	7

Table IV shows the anesthetic agents used. During the whole series the customs in anesthesia have remained much the same except that cyclopropane definitely increased, ethylene definitely decreased, and spinal anesthesia became much more largely used for the long abdominal operations. In the first series only 6 spinal anesthetics were given to the 155 patients with gastrectomies and 7 were given to the patients in the 127 other gastrointestinal cases. In the following 153 gastrectomies, 143 spinal anesthetics were given, and in the following 129 other gastrointestinal cases 109 spinal anesthetics were given. The first spinal anesthetics for these long operations were administered by the continuous technique but certain occasional inconveniences influenced us to change to the much longer lasting spinal anesthetic drug, nupercaine, with the single injection method. This provides spinal anesthesia for three hours or longer.

TABLE IV. ANESTHETIC AGENTS

	CYCLO- PROPANE	ETHYL- ENE	ETHER	PENTO- THAL	SPINAL	CURARE	TRACHEAL TUBE NO. (%)	LOCAL
Brain	102	18	6	7	0	0	119 92	0
Other neurosurgery	77	2	2	1	0	0	72 91	0
Chest	26	2	0	7	0	0	26 78	0
Gastrectomies	297	44	4	12	149	2	289 93	0
Other gastrointestinal	248	32	3	12	116	4	207 81	0
Miscellaneous	131	34	27	36	18	0	73 37	6
Total	881	132	42	75	283	6	786 78	6

It is most interesting to look back and consider the development of our anesthesia for the major abdominal surgery. Up to twenty years ago, the anesthesia was all drop ether. We considered then that any abdominal procedure requiring more than three hours carried more than a 50 per cent risk from both the anesthetic and surgical standpoint. While we used nitrous oxide with ether in some cases, we did not consider it much of an improvement. Twenty years ago we began to use ethylene, almost always with ether, and soon began to feel that a definite improvement had been made.

In the fall of 1933 we began to use cyclopropane but not until 1935 did we use it for major upper abdominal surgery and found that in nearly 50 per

cent of cholecystectomies, for example, we were obliged to add ether to the cyclopropane in order to obtain satisfactory relaxation. Our technique in the use of cyclopropane improved until by January, 1939, when the presently reported series of long surgical procedures began, we practically never found it necessary to use any ether. However, we have always been, and still are, required to produce cadaverous relaxation and almost unnoticeable breathing to expedite the surgical procedure. This we accomplished by employing a sufficient concentration of cyclopropane and by carrying on artificial or "controlled" respiration by manual manipulation of the breathing bag. It is interesting that of the 149 gastrectomies and 120 other gastrointestinal cases in this series, averaging five hours six minutes and four hours six minutes, respectively, before we had begun to use any spinal anesthetics for such cases, only two patients with gastrectomies and two patients in other gastrointestinal cases received any ether. We observed that the operative and postoperative course and recovery time of these patients were better than with any preceding type of anesthesia.

It was in April, 1942, that we began to extend our use of spinal anesthesia from the shorter abdominal operations to those which we were quite sure would require three hours or more of anesthesia. In all of such cases we have consistently induced general anesthesia as soon as the spinal anesthesia has been induced and confirmed. We do not believe it is necessary or helpful to submit the patient, in long procedures, to the weariness of lying awake even a part of the time. Besides, the manipulations necessary in any upper abdominal operations and bowel resections usually cause nausea and retching under spinal anesthesia alone, which is miserable for the patient and disturbing to the surgeon. The purpose of the spinal anesthesia is to spare the patient the prostrating effect of long, deep general anesthesia, and therefore we took pains to keep the level of general anesthesia in the first plane of the surgical stage as long as the spinal anesthesia remained effective. As the latter faded out, we deepened the narcosis as much as required to afford relaxation. Throughout both phases of the anesthesia we exercised controlled respiration as much as necessary to effect quiet respiratory movement. We were impressed by the fact that these patients who had been given spinal anesthesia looked even better postoperatively, had even less prostration, and recovered their vigor even more rapidly than those who had been anesthetized by cyclopropane alone.

It will be noted in Table IV that only 6 of the patients in the 1,000 long operations in this series received curare. The end of this particular series marks the beginning of our use of curare in such cases. We added curare to our armamentarium in May, 1943, and for several months used it only for abdominal operations lasting up to two hours. After thus becoming well acquainted with it, we began to use it in the long procedures at the dwindling of the spinal anesthesia relaxation, thus avoiding the deepening of the general anesthesia. These six cases represent the beginning of this further evolution and they were pleasing enough to encourage us to continue. Discussion of this experience, of course, goes beyond this presently reported series of 1,000 long operations, and will be reported in a later series. It should be said here, however, that, because of the occasional postspinal anesthesia headache and possibly a higher incidence of catheterization after spinal anesthesia, after a few months' trial of curare for prolongation of the relaxation, we began to substitute it for spinal anesthesia in our long procedures from the beginning. It has seemed that this has helped to bring about a still further gain in the

rapid return of vigor. As one surgeon expressed it, "These patients with 75 per cent or more gastrectomy now cannot see why they should not go home on the fourth postoperative day." They do average only seven and a fraction postoperative days in the hospital.

It must be emphasized, of course, that in addition to improved anesthesia, they receive excellent preoperative preparation and are given adequate operative and postoperative fluids, plasma, blood, and vitamins.

The twenty-four pentothals for gastrointestinal patients were all for induction only, and the tendency toward this use of it has increased largely in later cases.

It will be noted that of 129 cases of brain surgery, 102 patients received cyclopropane, 18 ethylene, 6 ether, and 7 pentothal. The last were for induction only, the ethers were for children, and the ethylenes were in some of the earlier cases, and some in which it was combined with cyclopropane. Cyclopropane is our standard method. In years past we used open ether, rectal ether, rectal avertin, and either of these supplemented with chloroform. We believed that any gas anesthetic was contraindicated because of increased intracranial pressure. The intratracheal tube settled the last point. Our neurosurgeon states that he likes our intratracheal cyclopropane better than others which we have used and others which he sees.

For our major chest surgery we have never used any anesthetic except intratracheal cyclopropane.

The use of the intratracheal tube has been one of our mainstays in the care of our patients during the anesthesia period in long surgical procedures. In brain surgery we consider it essential. It makes it possible to control the anesthesia, control respiration, and keep out of the way of the surgeon, no matter what may be the operative position. In looking at the figures, we are amazed that there were 10 cases in which the tube was not used. Most of them involved small children under special circumstances. In most other neurosurgical cases the tube is not quite so essential but makes for much greater efficiency because of prone, semiprone, or other odd position.

In open chest surgery we use the intratracheal tube consistently in spite of only 78 per cent shown in Table IV. Of the 7 patients who did not have it, some were tiny babies with tracheo-esophageal fistulas and some had extensive chest wall surgery.

All of our abdominal surgical patients come to the operating room with Wangenstein suction tubes through the nose into the stomach, and suction with the Wangenstein bottles is continued throughout the surgery. It is almost impossible to keep a perfectly fitting mask with the tube coming out under it. In addition to that, in spite of the constant suction, there is sometimes some gastric fluid which, because of manipulation, follows up the esophagus outside the tube and tends to enter the trachea unless the latter is occupied by the tracheal tube. Therefore, we use a tracheal tube in practically all gastrectomies and in the great majority of other gastrointestinal cases.

We use an intratracheal tube surrounded by an inflated cuff. The inflation is done with air under 14 to 16 cm. of water pressure. Measuring the inflation pressure was suggested by Dennis after we had injured a trachea by too great inflation with a syringe. Our tracheal tubes, cuffs, and water manometers are homemade in our division of anesthesiology. The type of cuff was worked out for our special needs by Grimm, with one of us (R. T. K.). This

provides an airtight fit without injury to the trachea, preventing the entrance of any foreign material and providing perfect control of respiration.

We have permitted the use of the cautery and the fulgurating current for all of our brain and neurologic surgery and for our gastrointestinal surgery except in a few individual instances in which we felt there might be some explosive gas present in immediate proximity to the spark or heat. We have felt that the type of anesthesia used and the benefit of the cautery or fulguration were both too advantageous to be given up, in view of the closed system of anesthesia and careful draping. With hundreds of trials we have failed to pick up an explosive sample of gas farther than three inches from the wide-open end of the gas tubing with three and four times the gas flow used in anesthesia, even though an explosive mixture was picked up each time from the tube itself. We do not believe that any inadvertent tiny leak can reach the cautery or spark.

Among the 1,000 patients with long surgical operations, 84 have had post-operative pulmonary complications, 17 of whom died and 67 recovered. The diagnoses were as follows, some having more than one diagnosis: atelectasis 27, pulmonary edema 7, bronchial pneumonia 30, pneumonia 10, pneumonitis 4, pulmonary emboli 6, and miscellaneous 6. There were 92 deaths from nonpulmonary complications.

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INTERCOSTAL NERVE BLOCK

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THE development of anesthesiology in recent years has been rapid, new agents and methods making possible operative procedures which in former years entailed either great danger or certain death. One of the most important of these has been the use of regional anesthetic procedures, which were popularized in large measure by the teachings and writings of Gaston Labat.

The field has been enlarged still further to include the use of regional procedures not only for operative interventions but also in diagnosis and therapeutics. Sympathetic block with procaine is used as a preoperative test to determine the efficacy of sympathectomy in essential hypertension. Lumbar paravertebral block relaxes the spasm associated with thrombophlebitis and helps relieve the pain from the impaired circulation. Subdural injections of absolute alcohol often eliminate the intractable pain of inoperable carcinoma.

The blocking of the intercostal nerves is one of the regional anesthetic procedures which has been developed largely in the last few years since Bartlett's¹ description in 1940. Its use in the relief of pain can be applied to a

variety of conditions. It has been tried and found of value as an anesthetic for operative procedures, in the relief of postoperative pain, in the relief of acute pleuritic pain, and in the relief of the pain associated with fractured ribs. These will be discussed individually.

TECHNIQUE

A description of the anatomy of the intercostal nerves will give a better insight into the benefits to be gained from their anesthesia. After arising from the spinal cord they pass out of the intervertebral foramina and run in a groove behind and at the lower border of their respective ribs between the internal and external intercostal muscles, giving off branches to the pleura. Upon reaching the costal arch they pass below the costal cartilage into the anterior abdominal wall and run toward the midline in an oblique downward direction to innervate the skin and muscles of the entire anterior abdominal wall with the exception of the inguinal regions. The nerves are most accessible in the region from the mid-scapular to the anterior axillary lines where they run in a closed compartment under and behind the rib, and it is in this region that the blocks are done.

The proper placement of the patient is quite important, and either of two positions may be used. When the block is being done before or immediately after an operative procedure, the patient is usually in the recumbent position. If it is being done therapeutically, the patient can either sit or assume the recumbent position. The arm should be raised above the head for two reasons, first, to remove it from the operative field, and second, to make the skin over the ribs taut to facilitate both the finding of the landmarks and the insertion of the needle.

With the patient in the recumbent position, a small pillow is placed under one side to raise the thoracic cage and make the operative field more accessible. The area is draped and surgically prepared with alcohol, ether, and a suitable antiseptic solution, using strict aseptic technique. Then, using a hypodermic needle, wheals are raised with 0.5 per cent procaine over the selected ribs at the desired site of injection, usually the midaxillary line. The intercostal block is performed by inserting a needle perpendicular to the skin until it strikes against the rib. Once contact is made with the rib the needle is moved down until it just slides past the undersurface of the rib where it now lies in close proximity to the intercostal nerve. The solution is deposited here, and after the needle is withdrawn the area is vigorously massaged. The needle used is an ordinary No. 20 gauge intravenous needle with a short bevel. The anesthetic solution is varied depending upon the desired result.

There are several precautions to be observed in the technique. Aspiration should always be done before injecting to avoid intravenous administration of the drug or injection into the pleural space. Strict asepsis should be used to avoid infection. Too much of the agent should not be used and the upper limits of safety in quantities of local anesthetics should be remembered.

USE IN OPERATIVE PROCEDURES

There are many relatively poor-risk patients who need upper abdominal operations. Many of these fall into the hypertensive arteriosclerotic older age group in whom high spinal or deep inhalation anesthesia would constitute a definite hazard. In these instances local anesthesia is often used, but un-

fortunately local infiltration of the area does not always produce enough relaxation for satisfactory surgery. In this group of cases intercostal nerve block is of great usefulness. When properly done it provides relaxation of the upper abdominal musculature with sensory anesthesia which is sufficient for opening the abdominal cavity. Although it can be used alone, it is best when in some form of balanced anesthesia.

Balanced anesthesia is a term originally used by Lundy² to describe the use of a combination of anesthetic agents and methods so balanced that the burden of pain relief and the production of conditions compatible with surgery are not borne by any one method but rather by the combined effects of several. Intercostal block is ideally suited to this type of procedure.

The first step in the production of any balanced anesthetic is the proper preoperative preparation of the patient. The effect to be desired from the premedication is the production of a sleepy, drowsy patient who can be easily aroused. This can usually be accomplished by the combination of a barbiturate, opiate, and one of the belladonna derivatives. The dosage is determined only after a careful estimation of the patient's strength and condition. In the average case, nembutal gr. 1½, morphine sulfate gr. 1/6, and scopolamine hydrobromide gr. 1/150 have proved quite satisfactory when given from one to one and one-half hours preoperatively. The barbiturate also helps ward off any toxic effects from the anesthetic solution.

After the patient has arrived in the operating room, the block is performed in the recumbent position as already described. Usually nerves VI through XI are injected bilaterally in the midaxillary line. When proficiency in the technique has been acquired, the whole procedure does not take more than ten minutes. After the block has been done, the surgeon must wait from five to ten minutes before complete anesthesia is present as shown by relaxation of the musculature and loss of sensation to skin stimuli. The agent used has been a 2 per cent solution of procaine without adrenalin. Three cubic centimeters injected into each interspace have invariably provided more than two hours of good anesthesia.

Although in some instances if the surgeon is very careful and gentle the operative procedure may be carried out with no further anesthesia, it is best to put the patient lightly to sleep with nitrous oxide or cyclopropane. The anesthesia need only be to the first plane of the third stage of anesthesia (after Guedel³). Relaxation has already been obtained through the nerve block.

Evans⁴ has recently published a report on the use of intercostal block plus sodium pentothal intravenously in surgery of the upper abdomen, referring especially to war injuries, where he finds the combination to be better than any other method available. In our civilian hospitals a beautifully balanced anesthesia can be produced using this combination plus a 50 per cent nitrous oxide-oxygen mixture. This case has previously been reported in a paper on intercostal block in balanced anesthesia.⁵

CASE 1.—E. G., a 64-year-old, obese, white woman with hypertensive arteriosclerotic heart disease and pyloric obstruction from carcinoma of the stomach was to have a gastroenterostomy.

Premedication was a combination of nembutal, morphine, and scopolamine. Intercostal block in this instance was done with the formula to be given later in this paper, containing monocaine base, benzyl alcohol, benzocaine and oil, 1½ c.c. at each interspace. After the skin

incision was made, she was put to sleep with a 2½ per cent solution of sodium pentothal injected into the tubing of an infusion which the patient was receiving. Immediately thereafter the mask of an anesthetic machine was applied to the patient's face and a 50 per cent mixture of nitrous oxide and oxygen was administered. This last made it possible to give her a high concentration of oxygen while providing a means of watching the depth of respiration. The nitrous oxide also lessened the amount of pentothal needed to keep the patient asleep.

The patient did very well during the operation with practically no change in the pulse or blood pressure. That evening, when she became thirsty, she got out of bed to get a drink of water. After being returned to her bed, she remained there during an otherwise uneventful recovery.

In this case the use of the intercostal block to produce relaxation allowed the use of small, relatively innocuous amounts of other agents to produce a satisfactory anesthesia. The use of any one agent to produce the same effect could not have been done without having an undesirable effect upon the patient.

The intercostal block can be used with any type of inhalation anesthesia and has proved very helpful with nitrous oxide, cyclopropane, and ether.⁵ The demand for great depth of anesthesia to produce upper abdominal relaxation is removed, and the beneficial effects to the patient are evident both in the condition during the operation and in the postoperative period.

USE FOR POSTOPERATIVE PAIN

After using the intercostal block in operative procedures for some time, the thought arose that if a long-acting anesthetic were used to produce anesthesia or analgesia of several days' duration, the patient could be spared the ordeal of postoperative pain, and with the relief of this pain would come freedom from its sequelae. The pain following upper abdominal operations and attempts to relieve it result in greatly reduced respiratory excursions. The factors involved are splinting of the diaphragm, tight abdominal dressings and binders, reluctance to take deep breaths, morphine, and other opiates, unwillingness to attempt to cough up gathering mucus, and the tendency of the patient to remain in one position. All of this leads to stasis of pulmonary secretions, atelectasis, and pneumonia. It was thought that if a prolonged anesthesia or analgesia of the operative area could be produced and these dangers eliminated, the incidence of postoperative pulmonary complications could be reduced while the postoperative period was made much more tolerable for the patient.

A survey of the literature revealed that Zollinger,⁶ in 1941, had apparently had a similar idea and attempted to produce anesthesia with a solution of eucupine in oil. Although his results were not uniformly good, he felt that the principle was sound and that the method warranted further investigation and clinical trial.

Accordingly, a search was made for a suitable agent, and a preparation with the following formula* finally selected:

Monocaine base	0.02 Gm.
Benzyl alcohol	0.05 Gm.
Benzocaine	0.03 Gm.
Oil of sweet almonds	to 1.0 c.c.

This solution had previously been used by Brenner⁷ in rectal work, and it was thought that it would prove satisfactory here.

*This formula is prepared and marketed under a trade name by the Novocol Chemical Mfg. Company, Inc., Brooklyn, N. Y., and a supply was generously provided for our use in these investigations.

Although there is some danger of abscess formation and sloughing when using oily solutions if too large a quantity is pooled in one place, it was felt that if only small quantities were injected in one place under aseptic conditions and then the area were thoroughly massaged, this danger could be eliminated. This proved to be true, for up to the present time more than 500 injections of this solution have been made with no local or systemic reactions of any kind being noted.

The injections were made according to the described technique, nerves VI through XI being injected bilaterally in the midaxillary line with $1\frac{1}{2}$ c.c. deposited at each space. The injections were usually made after the anesthetic being used for the operation had been induced, so that the patient would be spared the pain associated with the insertion of the needles. In the case of spinal anesthesia it was done after anesthesia was present to the level of the fourth thoracic segment, and when an inhalation method was being used it was done after the patient was asleep. In a few instances it was done at the close of the operation before the patient reacted.

A marked success was obtained in a series of twenty cases, a report of which has been published elsewhere.⁶ The patients were grateful for the comfortable postoperative period, and in those cases where the block was successful the incidence of pneumonia was zero. The method is still being used with the same good results.

As near as could be determined, the anesthesia produced lasted from eight to twelve hours, and was followed by a period of analgesia lasting for two to three days. These patients required little or no opiates for sedation.

This method of attempting to relieve the postoperative pain from upper abdominal operations seems to be the most practical and the most likely to succeed that has been advocated thus far. However, a much wider clinical trial is necessary before it can be properly evaluated.

USE IN FRACTURED RIBS

The same line of reasoning that prompted the use of a long-acting anesthetic for upper abdominal operations led to its use for fractured ribs. Even after adequate strapping of the chest many patients complain of pain at rest, or more often on motion, deep breathing and coughing. An attempt was made to alleviate this pain by intercostal block with the anesthetic oil solution, using the knowledge gained in its previous use. A limited number of patients have been treated in this fashion, with uniformly good results. The blocks were done with the patient in the sitting position, and 2 c.c. of the anesthetic oil solution were injected into each interspace. A typical case report is Case 2.

CASE 2.—J. S., a 59-year-old white man, came to the accident room complaining of pain in the left side of his chest since trauma three days previously. The patient had been strapped with no relief and had had no sleep since the accident. X-ray examination showed that ribs 7 and 8 on the left side had been fractured in the midaxillary line.

Intercostal block of nerves VI, VII, VIII, and IX was performed in the posterior axillary line with 2 c.c. of the anesthetic oil solution at each space, with the patient in the sitting position holding his arm above his head. In ten minutes he felt much better, and in twenty minutes the pain was gone. After restrapping he left the hospital free from pain, and smiling. He telephoned several days later to state that he had remained completely free from pain and was very comfortable.

In this type of case the intercostal block can be used to advantage if the fracture is anterior to the posterior axillary line and the injection can be per-

formed posterior to it. It must be remembered that there is an overlapping of the distribution of the intercostal nerves and that the block should always include one nerve above and one nerve below the ribs involved. It is a useful addition to the treatment of this condition and in the relief of the pain accompanying it. The treatment of the fracture itself is not changed in any way, and immobility by strapping or some other means is still to be desired.

USE FOR ACUTE PLEURITIC PAIN

One of the cardinal symptoms of a pneumonic process in the lungs is pleuritic pain, which often is quite severe and distressing to the patient. Price⁹ has reported a series of cases in which he used intercostal block in an attempt to relieve this pain with marked success. The method is simple and effective, often producing permanent relief. By allowing relatively free motion of the thoracic wall, which would otherwise tend to be splinted as a result of the pain, it favors adequate ventilation and aeration of the lungs, affording protection against the complication of atelectasis. Drainage of the involved area is promoted since coughing is rendered nearly painless. Opiates which ordinarily are given for pain depress the cough reflex and thus favor stasis with resulting atelectasis.

The nerves to be injected are those corresponding to the intercostal spaces over which definite tenderness can be elicited by slight pressure. The injection is made most conveniently in the posterior or midaxillary line. However, in cases where the hyperesthesia is located more posteriorly, injection can be made in the mid-scapular line. The injections are made with 2 c.c. of a 1 per cent solution of procaine hydrochloride, with the patient in either a sitting or a recumbent position.

Although my experience has not been as favorable as that of Price, since in most cases only partial relief from pain was obtained, the method has definite value if the patient can be helped even in small measure.

CONCLUSION

The recognition of the value of intercostal block as a regional anesthetic procedure has been slow in coming. Some have been hesitant to make use of it because of the danger of striking blood vessels or puncturing the pleura, others because of the extra time and trouble involved in its performance. If ordinary precautions are taken, the method is without any more hazard than any other procedure involving the injection of an anesthetic solution into the body. The time and trouble element should not be of major importance when the benefits to be derived are so great.

The discussion here has included the use of intercostal block as an anesthetic for operative procedures, for the relief of postoperative pain, and for the relief of pain from pleurisy and fractured ribs. It is hoped that this form of therapy will find wider favor and a larger field of application. Its simplicity and ease of accomplishment should make it a common procedure in the field of anesthesiology.

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NOTES REGARDING THE USE OF INTRAVENOUS SODIUM PENTOTHAL ANESTHESIA IN MAJOR SURGICAL CASES

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WE STARTED to use intravenous sodium pentothal as a general anesthetic for major surgical cases June 5, 1942, at the Missouri Baptist Hospital. It has been used in all surgical cases by myself, and several other surgeons have used it extensively for a grand total of 2,287 cases. It has been used in every type of major surgical case, excluding lung resection. The ages of the patients ranged from 7 to 92 years. It has been used in head and neck cases, goiters, breast resection, and all types of major abdominal operations including common duct stones with jaundice and some with high nonprotein nitrogens, shock and low hemoglobin cases, which were suitable for any other general anesthetic agent. There have been no deaths traceable to this anesthetic, no thrombosis, nor local necroses. We have used morphine and atropine but we usually give hyoscine and morphine in suitable doses according to the age of the patient and his general condition about thirty to forty minutes before operation, and a sleeping dose of some barbiturate the night before operation.

In the beginning, we used a 5 per cent solution, which was soon changed to a $2\frac{1}{2}$ per cent solution due to prolonged sleeping periods after operation. The dosage has ranged from $2\frac{1}{2}$ to 45 gr. in one case. Anesthesia has been maintained up to four hours without ill effect. We are now averaging from 15 to 25 gr. in most major cases, such as gall bladders, hysterectomies, etc. Anesthetists must be properly trained, alert, and capable. Relaxation is very satisfactory. There is practically no postoperative nausea. The agent is non-explosive and the equipment required is simple and inexpensive. We use the Thomas apparatus. The anesthetist is well away from the field of operation. In our early cases, from 10 to 15 gr. more of the drug were used than we now find necessary. The postoperative sleeping period ranges from one-half to four hours depending upon the preanesthetic dosage, the type of patient, and the type of operation.

The skin surface is carefully sponged with alcohol and usually the median vein is selected for puncture. When blood appears in the syringe, from 2 to 3 c.c. of sterile, chemically pure, distilled water is injected followed by the $2\frac{1}{2}$ per cent pentothal solution made with sterile, chemically pure, distilled

water in ampules. Complete anesthesia with good relaxation is obtained in from ten to thirty seconds and usually after having used from $2\frac{1}{2}$ to $7\frac{1}{2}$ gr. of pentothal in $2\frac{1}{2}$ per cent solution. Alcoholics and some other types require heavier initial dosage. Appropriate amounts of solution are then injected from time to time to maintain suitable relaxation, usually 2 to 3 c.c. at a time. In all major cases, 100 per cent oxygen is given throughout, due to shallow respiration caused by sodium pentothal. When the operation is almost completed, after peritoneal closure, the lungs are ventilated with oxygen, 95 per cent and carbon dioxide, 5 per cent. Any indication of overdosage is met by giving 100 per cent oxygen under moderate pressure and an open airway. The airway is used throughout the operation and the patient is sent to bed with the airway in position unless earlier ejected by him. Oxygen and carbon dioxide are administered routinely at intervals for about twenty-four hours postoperatively in all upper abdominal cases.

Much time is saved and there is no unpleasant sensation for the patient after the initial puncture. The patients seem uniformly well pleased and in fact many new patients are now requesting this drug. In prolonged procedures such as stomach resections, etc., after the initial induction with $2\frac{1}{2}$ per cent solution, a continuous flow of $\frac{1}{2}$ per cent solution is sometimes used, by Murphy drip, the rapidity of flow being regulated from time to time by the anesthetist.

We have four nurse-trained anesthetists who quickly grasped the technique of promptly puncturing the veins under aseptic precautions, first injecting 2 or 3 c.c. of sterile water to make certain that the needle is properly in the vein before the pentothal solution is used. They soon learned to judge when to give additional amounts in order to maintain relaxation with a minimum amount of the drug. Increased respiration and increased muscular tension are indications for additional dosage.

It is our considered judgment that sodium pentothal can be used safely in major surgery and to greater advantage than any other anesthetic agent now available. Careful records have been made and are available in all cases.

CURARE IN ANESTHESIA

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THE employment of curare* as an anesthetic accessory for the enhancement of muscular relaxation is now becoming more universal. The technique appears to be withstanding the rigors of use in increasing numbers of cases in favorable and unfavorable circumstances by both the experienced and inexperienced anesthetist. The exact allocation of the drug's importance in the field of anesthesiology cannot yet be determined, but clinical and laboratory experience with the drug has uncovered certain desirable and undesirable properties, knowledge of which will assist in establishing its safe and rational utilization. It is the purpose of this communication to outline these properties.

Sustentative evidence¹⁻⁴ gives credence to the theory that the basic action of curare is its ability to minimize or prevent response to acetylcholine. Curare is apparently capable, then, of influencing any structure whose function depends on mediation of nerve impulses by acetylcholine. This concept is helpful in comprehending the effect of the agent on organs innervated by the somatic or the autonomic nervous systems. The effect of the drug is directly proportional to the concentration of the drug at the site of action. The action is reversible and can be accomplished by increasing the concentration of, or the length of action of, acetylcholine. This increase in concentration or prolongation of action of acetylcholine can be produced by strengthening the nerve impulse, adding acetylcholine artificially, or inhibiting the action of cholinesterase with drugs such as physostigmine or prostigmine. This latter method is the most convenient means of overcoming excessive curarization in clinical practice. There is some evidence that curare may kill by depressing the peripheral circulation,⁵⁻⁷ but the majority of deaths from curare are due to asphyxia accompanying unrelieved respiratory paralysis.⁸

The coveted action of curare in clinical practice is that degree of depression of muscular activity that provides suitable relaxation at the site of operation without undue paralysis of the muscles of respiration or prostration of the peripheral circulation. Fortunately, this optimal state can be achieved by judicious use of the drug, and the frequency of its attainment is directly proportional to the experience of the employer. The technique by which this state can be obtained has been amply covered in other publications and remains a standard procedure.⁹⁻¹⁴ Muscular paralysis is achieved by preventing the receptor substance of the muscle from responding to acetylcholine. The muscle cells are unaffected and may be stimulated to full action, in the presence of curarization, by electrical means. The nerve leading to the muscle is likewise unaffected by the curare. It is of considerable interest and importance in the clinical use of curare to know that certain of the anesthetic agents, notably ether, possess curariform actions of their own and the amount of curare used in conjunction with these agents must be significantly reduced.⁴

Experimental and clinical data^{5, 15, 16} seem to indicate that curare has no direct or indirect effect on the heart. The drug has been used on patients

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*Intocostrin, E. R. Squibb & Sons, New Brunswick, N. J.

with and without cardiac abnormalities and in the presence of agents that are prone to produce arrhythmias, and no alterations attributable to the curare can be segregated. Peripheral circulatory depression, however, does develop in a few patients in whom curarization is present. This reduction in blood pressure may be due to a direct relaxing effect on the smooth muscle of the arterioles or to widespread muscle relaxation with consequent impaired venous return and lowered cardiac output. It is associated with either excessive single doses administered in a short time or to rather complete curarization over long periods of time such as is necessary in the treatment of tetanus with this drug. The circulatory detrusion is usually of brief duration and recovery occurs without specific therapy. In patients with labile vascular systems, it may be profound and refractory to treatment. In the latter type of case, it might be possible to precipitate a fatal termination of the anesthetic procedure. It is important, for this reason, to use the curare cautiously and avoid large single doses or protracted curarization.²

The action of curare on the gut has been studied.⁶ The small intestine consistently exhibits brief cessation of peristalsis and somewhat longer periods of loss of tone with therapeutic amounts of the drug in the unanesthetized animal. The cessation of peristalsis lasted usually only two to three minutes. In a few animals it lasted approximately twenty minutes. The loss of tone persisted for about twenty minutes with a gradual return to normal. Morphine and cyclopropane obliterated the curare effect. The effect of curare on the stomach was inconclusive. The etiology of the cessation of peristalsis and the loss of tone produced by the curare may be one or the other or a combination of two factors. The drug was shown to have a direct effect on isolated small bowel and it is known also that curare inhibits to some extent the action of the vagus nerve.^{2, 6} It is impossible with the available data to determine which of the factors is dominant. It is anticipated that no residual action of curare will remain which might predispose toward postoperative ileus.

There is minimal detoxication of curare in the liver and most of it is excreted unchanged by the kidney. Although it might be surmised, there is no evidence as yet that liver or kidney damage results in cumulative depression.

The effect of the drug on the uterus has not been studied. A number of patients have been given curare for purposes of abdominal muscle relaxation during cesarean section without any apparent effect on the infant.¹⁷ Studies have not been made on alterations of the blood elements and chemistry by curare.

Curare has no analgesic property and in situations in which pain relief is necessary, the relief must be secured by the most appropriate agent and technique. Curare may be used with any of the inhalation agents, with pentothal sodium, with intrathecal techniques if analgesia is present, tribromethanol in amylene hydrate, and with topical, regional, or infiltration techniques. As pointed out earlier, the dose must be adjusted according to the curariform properties of the agent used. The action of curare is restricted to approximately twenty minutes. It is advisable then, when using inhalation anesthesia, to use an agent that has the ability to provide moderate muscular relaxation by itself. The curare is preferably used to produce only added relaxation when the occasion demands. When the less potent inhalation agents are used, all the relaxation must be obtained with the curare, and the hazards attending its excessive and prolonged use appear. The use of curare with a topical anes-

thetic technique is limited chiefly to endoscopic manipulations during which it is difficult to obtain sufficient relaxation to permit easy and nontraumatic examination.¹⁸

SUMMARY

Curare has proved useful as a means of obtaining improved muscle relaxation during anesthesia. It is a safe drug when used in the proper fashion. Its chief disadvantage is the relatively narrow margin between the optimal dose and the dose producing respiratory paralysis. It should be used only when means of producing efficient artificial respiration and prostigmine are immediately at hand. It should be used only by those experienced in the science and art of inhalation anesthesia and should not be used to cover up errors of commission and omission in the anesthetic technique. It will gain and retain respect as a useful adjunct to anesthesia if it is employed within the limits of its pharmacologic properties and is not abused by excessive and indiscriminate use.

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ANESTHETIC AGENTS AS FACTORS IN CIRCULATORY REACTIONS INDUCED BY HEMORRHAGE

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INTRODUCTION

EXPERIMENTS designed to investigate shock in the laboratory have regularly utilized anesthesia as a means of immobilizing the animal for the technical procedure. Although an extensive variety of drugs has been employed for this purpose, minor consideration has been given to the fact that the influence of anesthesia on different functions of the organism varies widely with the agent employed.

Recent reports by Wiggers,¹ Blalock,² and Allen³ have directed attention to the necessity for standardizing the anesthetic technique so as to obtain a uniform degree and duration of narcosis. These and other reports, however, have neglected the specific complications which arise from anesthesia during the experiment. Without more objective knowledge of the variables introduced, it is difficult to evaluate and compare the conclusions and concepts proposed by different investigators.

Despite the renewed interest in the importance of anesthesia with respect to the circulation, no detailed study has appeared on the specific effects of anesthetic agents on the peripheral circulation, either in normal animals or those in shock. Recently, Bennett, Bassett, and Beecher⁴ determined the effects of several anesthetic drugs on the changes in blood flow in several major blood vessels of dogs following hemorrhage. The present study was undertaken to clarify the effects of some commonly used anesthetic agents on the circulation by utilizing changes in the circulatory dynamics of the capillary bed.

METHODS

The changes in the peripheral circulation resulting from a standardized bleeding procedure were followed in seventy dogs anesthetized with six different drugs. Plasma protein and hematocrit readings were routinely obtained prior to bleeding and induction of anesthesia. Plasma protein was determined by the falling-drop method of Barbour and Hamilton, and the hematocrit value by centrifuging in Sanforth-Magath tubes. The femoral artery was cannulated after local tissue infiltration with 2 c.c. of a 1 per cent solution of procaine, and blood pressure was recorded continuously, using heparin as an anticoagulant in the cannula. Following the induction of anesthesia, the omentum was exteriorized for direct microscopic study according to a method previously described.⁵ The essential feature of this method is the withdrawal of part of

This work was aided in part by a grant from the Josiah Macy, Jr. Foundation, New York. A preliminary report appeared in *Proc. Soc. Exper. Biol. & Med.* 56: 73-77, 1944. It constitutes the seventh of a series of studies on various phases of experimentally induced shock. The first study is listed as Ref. 5, the fourth as Ref. 11, the fifth as Ref. 12, and the sixth as Ref. 13 in the reference list of the present paper. The second study on acute hemorrhage, appeared in *Am. J. Physiol.* 139: 123-128, 1943; and the third on blood pressure technique, in *J. Lab. & Clin. Med.* 28: 886-888, 1943.

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the omentum into a rubber sheath attached to the peritoneal margins of the abdominal incision and exposure of a small portion of omental tissue over a glass horseshoe resting in a specially prepared moist chamber. The exteriorized omentum is maintained at body temperature and the exposed region kept in a moist condition by a continuous drip of warm Ringer's solution buffered with sodium bicarbonate to a pH of 7.3 and containing sufficient gelatin (1 per cent) to give it a colloidal osmotic pressure similar to that of a serous exudate. With these precautions, it is possible to keep the capillary circulation under observation for five or six hours with its normal reactivity intact. The omental criteria studied were (a) the rate and distribution of blood flow, (b) vasomotion, and (c) epinephrine reactivity of the muscular components of the capillary bed.

Dogs receiving only local anesthesia served as a control series with which the anesthetized groups could be compared. The controls were prepared for observation of the omentum with an abdominal field block using 8 to 10 c.c. of 1 per cent procaine solution and received no further medication.

As an additional means of observing the effects of hemorrhage on unanesthetized dogs, the omentum was prepared for observation in eleven animals by administration of cyclopropane or pentothal only during the required surgery. The dogs so prepared during cyclopropane anesthesia were allowed to recover consciousness for one hour before the bleeding was begun. Their behavior was very similar to that of the dogs receiving local anesthesia only, and the data concerning them were not included. Pentothal was found to be unsuitable for such preparations since its effects on the peripheral circulation persist for several hours after the dog has recovered consciousness.

The experimental dogs were divided into five groups, each of which was subjected to a different anesthetic procedure. The drugs used were: morphine sulfate (ten dogs), cyclopropane (nine dogs), ether (five dogs), sodium pentobarbital (twelve dogs), and sodium pentothal (eight dogs). Anesthesia was continuous throughout the experiment.

Morphine sulfate, 2 mg. per kilogram of body weight, was injected intravenously. This dose produced mild depression in the animal and a euphoric state which could not be considered complete anesthesia.

Cyclopropane and ether were administered, intermittently with oxygen, by means of a standard Foregger metric anesthesia table with a closed to-and-fro rebreathing system and a cannister for carbon dioxide absorption. Following the induction of anesthesia with a special face mask, an endotracheal catheter was introduced to assure an adequate airway throughout the experiment. The uppermost (first) plane⁶ of surgical anesthesia was maintained, in which spontaneous respiration is not depressed and the blink and corneal reflexes are brisk. The oxygen content of the respired anesthetic mixtures was always far in excess of metabolic requirements (75 to 90 per cent).

Sodium pentobarbital was given in a single intravenous dose of 25 to 30 mg. per kilogram of body weight. This amount produced about forty minutes of fairly deep surgical anesthesia, which gradually diminished over the succeeding two and one-half to three hours. As the surgical procedure and initial observations normally required forty to fifty minutes, these animals at the time that bleeding was instituted were in a depth of anesthesia comparable to that of the other anesthetized dogs. Five of the dogs in this group, to whom oxygen was given by endotracheal catheter, exhibited no demonstrable differences from those breathing air.

Sodium pentothal (1 per cent solution) was administered intermittently by vein from an infusion drip bottle in volumes sufficient to maintain a degree of narcosis similar to that induced by the inhalation agents. This required an average of 9.6 mg. per kilogram per hour, a relatively small dose of pentothal. All of these dogs received oxygen.

The bleeding procedure consisted of an initial blood loss of 2 per cent of body weight and the subsequent removal of 0.5 per cent at thirty-minute intervals. Bleedings were continued until a cessation of blood flow occurred in the large omental arteries. This was considered the maximal blood loss, since experience in bleeding over 150 dogs has demonstrated that further hemorrhage invariably results in a precipitous collapse of the animal. No sustaining infusions were given, and the dogs were left until they either showed signs of circulatory collapse or had maintained an adequate blood flow for at least two hours after the final blood loss. The dogs which collapsed spontaneously were infused with the blood withdrawn. The remainder of the dogs were given a similar infusion three hours after the last bleeding. Note was made of the degree of improvement of the peripheral circulation and of blood pressure for forty-five to ninety minutes. Autopsies were done on representative dogs in each group.

In addition to noting blood loss, blood pressure, and the omental criteria, atrial blood samples were taken every twenty-five to thirty minutes after each bleeding through a catheter passed down the right jugular vein to the level of the right atrium. These samples were analyzed for (a) venous oxygen, (b) uric acid, and (c) vasoexcitators and vasodepressors. The oxygen determinations were made by Roughton and Scholander's syringe method.⁷ Plasma uric acid levels were determined with an electrophotometer, using the colorimetric method of Brown. The sensitive reactions of the peripheral blood vessels to abnormal substances in the blood were utilized for detecting the presence of vasoexcitators and vasodepressors. Serum obtained from the hemorrhaged dogs was injected into normal rats and the effect on the rat mesoappendix noted.⁸

RESULTS

Table I presents data on fifty-seven normal dogs divided into a control series (thirteen dogs) and an experimental series (forty-four dogs). It was found convenient to classify the data into separate categories, each corresponding to a single circulatory criterion. Within each category, the results were tabulated as average figures. A sufficient number of cases to obtain uniform results was included in each anesthetic group. The hematocrit and plasma protein values were within normal limits. It will be noted that initial venous oxygen values were fairly high in those animals receiving oxygen endotracheally, an observation previously described.⁹

Tolerance to Blood Loss.—The maximal blood loss for each animal was determined. By bleeding the dogs at thirty-minute intervals, it was possible to withdraw from 3.2 to 6.7 per cent of their body weight in blood without causing the abrupt death of the subject. These values should not be confused with the bleeding volume which other investigators have obtained by exsanguination. With the method used in this study, all of the dogs survived for one or more hours after the last bleeding.

As noted in Table II, the ability of the animal to withstand hemorrhage varied significantly according to the anesthetic agent employed. The largest maximal blood loss was obtained in the control group. The animals in this group also showed the longest survival period and readily recovered following

TABLE I. AVERAGE NORMAL VALUES PRIOR TO HEMORRHAGE

ANESTHESIA	NO. OF DOGS	NORMAL MEAN BLOOD PRESSURE (MM. Hg)	NORMAL HEMATOCRIT (%)	NORMAL PLASMA PROTEIN (GM. %)	ANESTHETIC DOSE	OXYGEN	NORMAL BLOOD URIC ACID (MG. %)	NORMAL VENOUS OXYGEN (VOL. %)
<i>Controls:</i>								
Procaine abdominal block	13	147	50 \pm 3	6.00 \pm 0.5	8-10 c.c. 1% procaine	Not used	1.2	13.99
<i>Experimentals:</i>								
Morphine	44							
Cyclopropane	10	142	45 \pm 3	5.80 \pm 0.5	2 mg. per kg. Plane I, stage III, surgical anesthesia	Not used	0.8	14.4
	9	132	43 \pm 6	5.55 \pm 0.5		Used	0.9	17.18
Ether	5	139	49 \pm 2	5.67 \pm 0.3	Plane I, stage III, surgical anesthesia	Used	0.85	19.20
Pentobarbital	12	147	44 \pm 1	5.80 \pm 0.4	25-30 mg. per kg.	Used	1.2	16.15
						5 dogs		
Pentothal	8	164	48 \pm 3	5.76 \pm 0.4	9.6 mg. per kg. per hr.	Used	1.0	15.3

TABLE II. DATA FOLLOWING HEMORRHAGE

ANESTHESIA	MAXIMAL BLOOD LOSS	% SPONTANEOUS COLLAPSE < 3 HR. AFTER LAST BLEEDING	% REVERSIBLE TO TRANSFUSION 3 HR. AFTER LAST BLEEDING	CRITICAL BLOOD PRESSURE LEVEL (MM. Hg)
Procaine abdominal block	5.3	23	92	35-45
Morphine	4.6	60	70	40-50
Cyclopropane	4.8	33	89	40-45
Ether	4.1	80	20	75-85
Pentobarbital	3.8	75	25	55-65
Pentothal	4.0	100	0	80-85

"Maximal Blood Loss" represents average figures. "% Spontaneous Collapse, etc.," notes the frequency of circulatory collapse within three hours after final bleeding. Infusions were administered to dogs when collapse occurred and to all other dogs at the end of three hours. "% Reversible, etc.," indicates the percentage of dogs which could be recovered by transfusion. "Critical Blood Pressure Level" is that below which circulation deteriorated rapidly.

transfusion. Several of the dogs in the control group were observed for over twelve hours. These required no sustaining infusion and showed no signs of deterioration. In the morphine group, although the dose produced only a euphoric state and not complete anesthesia, it did significantly lower the dogs' ability to tolerate hemorrhage as compared with the controls. Of the four groups subjected to inhalation or intravenous anesthesia, the dogs in that group given cyclopropane showed a resistance to blood loss which most closely approximated that of the control group. These dogs survived for at least three hours and always responded well to transfusion. As indicated in Table II, 33 per cent of this group collapsed spontaneously and 89 per cent recovered as a result of transfusion alone. The ether-treated animals averaged a maximal blood loss of 4.1 per cent, and their survival time never exceeded two hours. Moreover, they were refractory to transfusion and did not respond when their original blood volume was finally restored.

The animals in the two groups subjected to barbiturate anesthesia withstood less hemorrhage than the others. Those given pentobarbital showed fairly uniform blood loss figures, averaging 3.8 per cent. Seventy-five per cent of the animals in this group collapsed spontaneously within three hours after the last bleeding, and the same proportion was irreversible to transfusion. The dogs receiving pentothal were less uniform both as to tolerance to blood loss and as to survival time. During pentothal anesthesia two patterns of behavior were noted, as previously reported,¹⁰ although the data in Tables I and II show only average figures for the group as a whole. One pattern of behavior (five dogs) was characterized by high initial blood pressures (170 to 175 mm. Hg) after the onset of anesthesia and by greater tolerance to hemorrhage and longer survival time than was noted in the remaining members of this group. The second pattern of behavior resulting from pentothal was characterized by an initial fall in blood pressure (to 105 to 112 mm. Hg), smaller blood loss figures, and shorter survival times. Both of the barbiturate groups showed a progressively poorer response to transfusion in the interval after the last bleeding. With pentothal, all of the dogs collapsed spontaneously and none was reversible with infusion.

When ether or barbiturate anesthesia was employed, extreme care was required in estimating the maximal blood loss. This was especially true with ether, where the loss of as little as 4 to 5 c.c. of blood per kilogram in excess of the omental end point frequently resulted in the sudden collapse of the animal.

For each anesthetic procedure, a characteristic range of blood pressure levels was maintained for a variable time after maximal blood loss before collapse ensued. This is referred to in Table II as "critical blood pressure" and represents a blood pressure range below which the condition of the dog rapidly deteriorated.

Inadequacy of Blood Pressure as a Circulatory Criterion.—Blood pressure proved to be the least reliable of all the circulatory criteria employed. Following equivalent blood loss, the fall in blood pressure varied considerably from animal to animal so that no accurate correlation could be made between the blood pressure levels and blood loss during anesthesia with any one agent. Even less reliable were comparisons between blood loss and blood pressure during different anesthetic procedures (see Fig. 1). For example, with hemorrhage of 3.5 per cent (Table I), the blood pressure with abdominal field block

PERCENT DROP IN BLOOD PRESSURE FROM INITIAL LEVEL

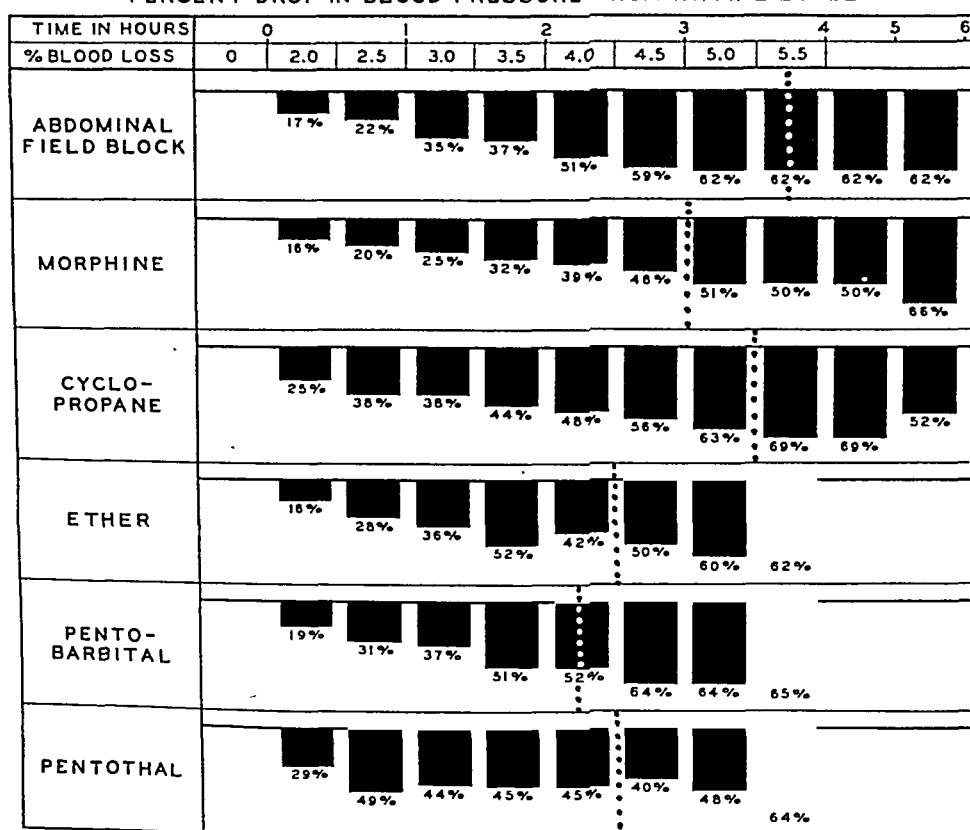


Fig. 1.—Dotted vertical lines in each group indicate final bleeding. Changes during bleeding are shown to the left of the line and those occurring after final bleeding to the right.

was 75 mm. Hg; with cyclopropane, 110 mm.; and with pentobarbital, 54 mm. Further evidence of the unreliability of blood pressure levels was obtained by comparing two dogs with similar blood pressures under the same anesthesia. After being given pentothal and bled 3.0 per cent, Dogs 126 and 138 both had blood pressures of about 85 mm. In spite of this, their other circulatory data revealed a markedly dissimilarity.

Blood pressure readings were also not a reliable index of the dogs' ability to withstand further hemorrhage and did not serve as a prognostic indication of survival time. For example, animals during ether or pentothal anesthesia usually showed blood pressures of 85 to 95 mm. following the last bleeding.

This criterion by itself indicated no immediate danger of circulatory collapse. However, not only was further bleeding contraindicated, but most of these animals died within forty to eighty minutes. In the groups receiving procaine and morphine, comparatively low blood pressure levels (35 to 50 mm.) were reached before maximal blood loss was attained. The low blood pressures alone would have condemned further hemorrhage and indicated a short survival time. Actually, these dogs tolerated additional blood loss up to 1 per cent of body weight and were among those which survived longest.

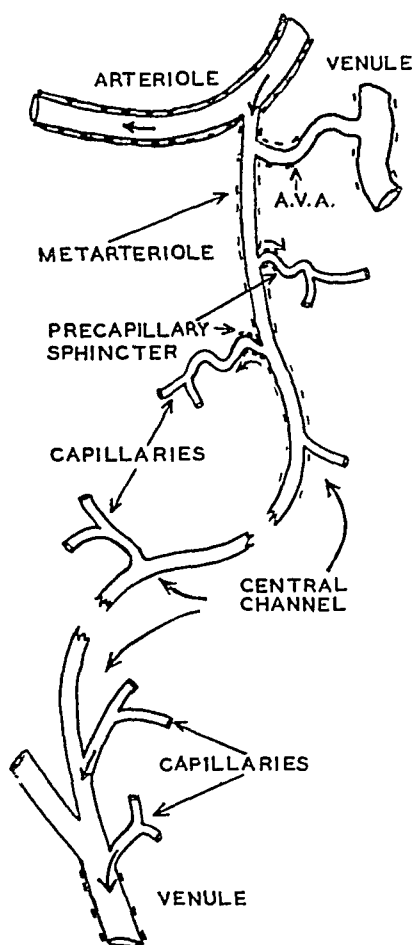


Fig. 2.—Structural pattern of a typical unit. Nomenclature and distribution of muscular components are indicated.

During each bleeding the blood pressure dropped abruptly to very low levels. When bleeding was discontinued, this condition was succeeded by an immediate increase in blood pressure. The rate and height of this rebound varied with the anesthetic agent used. The loss of this compensatory rebound in blood pressure usually occurred as the dogs approached their maximal blood loss.

Peripheral Circulatory Criteria.—Previous studies¹¹⁻¹³ on the circulatory changes in hemorrhagic and tourniquet-induced shock have demonstrated that the specific reactions of the different components of the capillary bed are sufficiently pronounced to serve as criteria for identifying progressive stages in the syndrome (see Fig. 2 for terminology). The degree to which the peripheral blood vessels participate in the compensatory reaction following blood loss is reflected in the adequacy of the flow through the capillary bed, that is, rate

of flow and the ability to restrict the circulation to the most direct capillary channels.

The peripheral mechanism restricting the blood flow to certain channels of the capillary bed is the maintenance of an augmented vasomotion of its muscular components. Vasomotion consists of a periodic contraction-relaxation cycle of muscular metarterioles and precapillaries. Such vasomotion, by controlling the patency of the centrally located vascular channels and their branches, conditions the distribution of blood through the entire capillary network. Loss of vasomotion results in an overfilling of the bed.

The reactivity of the smooth muscle elements of the capillary network was studied by noting their reaction to epinephrine topically applied. The minimal effective concentration of epinephrine was determined for each dog prior to bleeding by applying the drug to the surface of the omentum and noting the concentration which produced a narrowing of the metarterioles just sufficient to slow capillary flow.

Early in this study it was observed that variations in the peripheral circulation occurred simultaneously with changes in the depth of anesthesia. For this reason it was found essential to maintain the dogs consistently in the upper first plane of surgical anesthesia. Despite this, the different anesthetic agents produced characteristic differences in the normal peripheral circulation.

Variations in Unbled Dogs With Different Anesthetic Agents.—Blood flow, except in the pentothal and ether groups, was rapid and periodically became restricted. With pentothal and ether, flow was rapid but not restricted.

With ether and pentothal, vasomotion was slowed and in some instances was not present. During cyclopropane anesthesia, vasomotion was more active than in the controls, while in those dogs given morphine no difference from the controls was noted. The dose of pentobarbital caused a slight diminution of vasomotion.

The morphine and control groups showed comparable epinephrine reactivity, the minimal effective concentration being between 1 part in 3 million and 1 part in 6 million. In the pentothal and cyclopropane groups high reactivity was noted, ranging from 1 part in 10 million to 1 in 20 million. Ether and pentobarbital anesthesia lowered the reactivity (1:2 to 4 million) below that of the control group.

Omental Blood Flow as an Index of Circulatory Efficiency.—The feature which most accurately reflected the condition of the animal following hemorrhage was the ability to maintain an effective capillary blood flow. Blood loss up to 2.5 per cent had no significant effect on capillary blood flow in any experiment. The effect on the peripheral circulation was restricted to a narrowing of the large muscular arteries to about one-half their original diameter and a less marked narrowing of the accompanying veins. With more severe blood loss, slowing of the capillary flow occurred during each bleeding and was succeeded by a partial restoration of the former rate of flow. As blood loss approached maximal volumes, blood flow in the larger vessels was considerably slowed, while that in the capillary bed showed a transient stagnation. When maximal blood loss was attained, the entire peripheral flow ceased during the bleeding.

Fig. 3 depicts the progressive changes in blood flow resulting from hemorrhage during the different types of anesthesia. The least disturbance in blood flow occurred in those groups (procaine, cyclopropane, morphine) which

had the highest blood loss figures. The omentum became relatively ischemic as a result of the extreme vasoconstriction of the larger vessels. However, the capillary blood flow remained comparatively rapid by virtue of the restriction of the circulation to the most direct capillary channels. Under these conditions, the venular outflow remained adequate even at blood pressures as low as 35 to 40 mm.

Those groups which showed poor tolerance to bleeding developed an inadequate capillary circulation soon after maximal blood loss. During ether anesthesia, blood flow slowed sooner than during any other type of anesthesia. A unidirectional flow through the larger vessels persisted up to the point of maximal blood loss. The pentothal group showed an abrupt deterioration of capillary blood flow soon after reaching maximal blood loss. Capillary flow never developed the same degree of restriction as in the controls. A progressive decrement in capillary flow occurred in the pentobarbital group after the third bleeding (3 per cent).

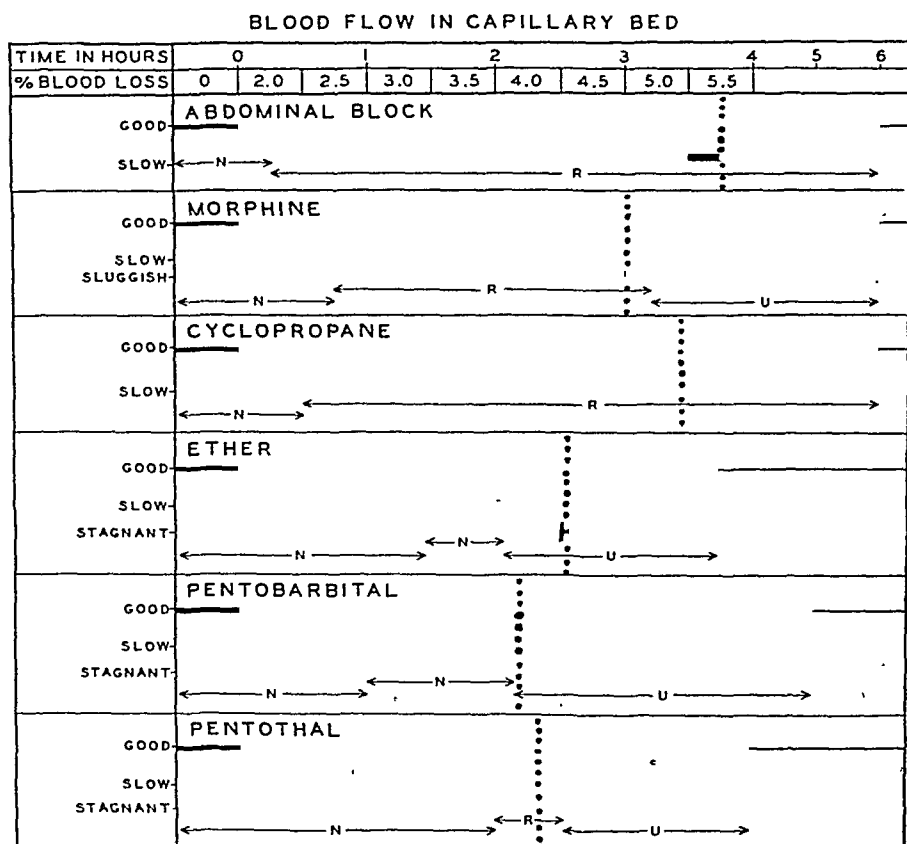


Fig. 3.—Changes in rate of blood flow are indicated by extent of deviation below normal base line. Dotted vertical lines indicate average maximal blood loss. N, normal distribution of circulation; R, period of restricted capillary flow; and U, unrestricted, with a loss of ability to confine flow to central channels.

With ether, pentobarbital, and pentothal, spontaneous collapse occurred in almost all the dogs twenty to ninety minutes after the final bleeding. The incipient circulatory failure was detected in the omentum by the development of stagnation in many of the capillaries and venules and by the occurrence of backflow from the larger veins. Spontaneous collapse occurred only in a small percentage of the dogs given procaine and cyclopropane. In instances where it occurred, the collapse was sudden, with no previous evidence of capillary

stagnation, an adequate capillary flow being maintained to within five to ten minutes of death. In the morphine group, spontaneous collapse occurred in 60 per cent of the animals. Omental blood flow in these showed only a moderate slowing to within fifteen to twenty minutes of death.

Vasomotion Following Hemorrhage.—Fig. 4 presents diagrammatically the changes in vasomotion following bleeding with the use of various anesthetic procedures. The phenomenon of vasomotion in the capillary circulation is the counterpart of vasoconstriction in the larger peripheral blood vessels. Both mechanisms appear almost simultaneously following hemorrhage. In this study the degree of narcosis utilized had no demonstrable effects on the vasoconstriction of the larger omental blood vessels. However, the different anesthetic agents did modify the amount of vasomotion prior to and following hemorrhage.

VASOMOTION IN CAPILLARY BED

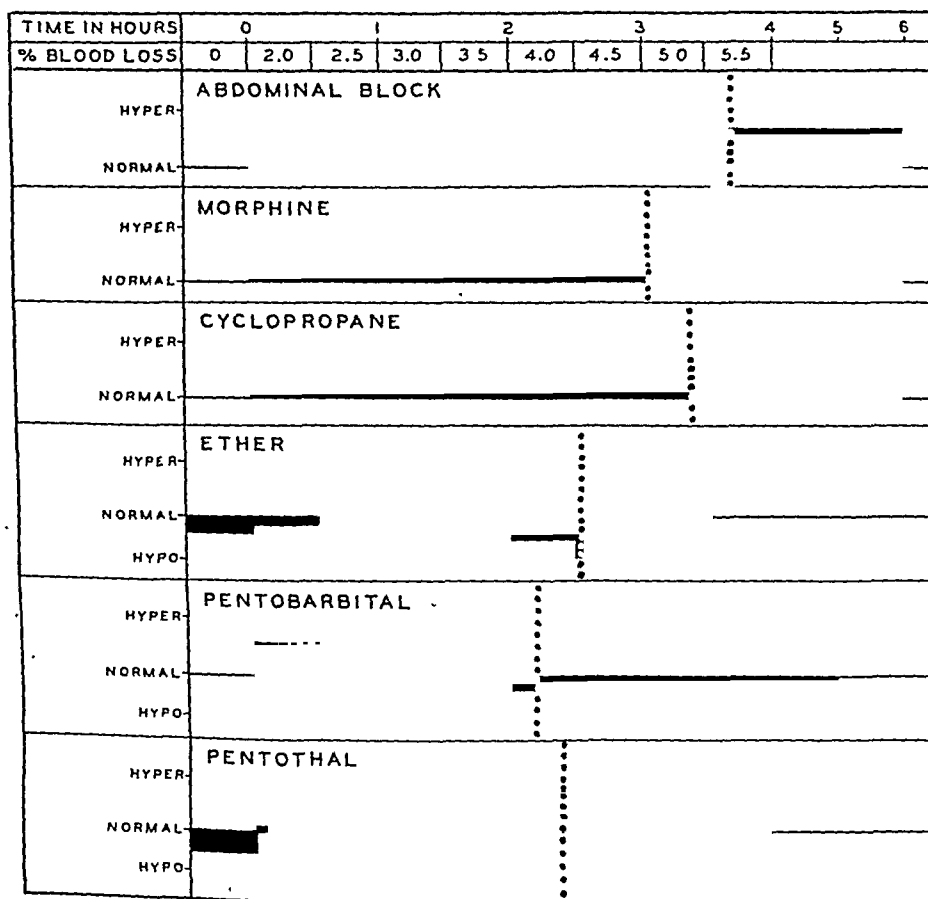


Fig. 4.—Dotted vertical lines indicate final bleeding.

In the control group, vasomotion recurred periodically at approximately one- to three-minute intervals. Within five to ten minutes following a 2 per cent blood loss, the constrictor phase of vasomotion began to predominate. Within twenty minutes its periodicity had increased to about one cycle every twenty seconds. This type of activity persisted throughout the experiment, that of the precapillaries becoming especially prominent. As a result, a continuous blood flow was restricted chiefly to the metarterioles and the central channels connecting them directly with the venules. The capillaries, most of which arise as side branches of these central channels, revealed only a sporadic, intermittent flow.

In the members of the group subjected to cyclopropane, an augmented vasomotion became evident soon after the onset of bleeding and, as in the controls, this activity was maintained throughout the period of observation. Dogs given morphine rapidly developed, after bleeding, an augmented vasomotion, which then decreased gradually and returned to its original level soon after maximal blood loss was reached.

The group receiving pentobarbital showed first a progressive increase and then a slow decrease in vasomotion over a three-hour period. Within thirty minutes after maximal blood loss was reached, vasomotion had disappeared completely. As previously mentioned, pentothal and ether anesthesia dampened vasomotion even prior to hemorrhage. When pentothal was used, vasomotion did not increase to the extent noted in the control group until a blood loss of approximately 3.5 per cent had been attained. It was then maintained at a high level until just following maximal blood loss, at which time it deteriorated rapidly and disappeared completely within forty-five minutes. Blood loss during ether anesthesia resulted in a moderate increase in vasomotion for about sixty minutes. Vasomotion then fell progressively to subnormal levels, being completely absent approximately twenty minutes after the last bleeding.

The persistence of active vasomotion was closely related to the maintenance of an adequate capillary circulation. When the blood flow was slowed sufficiently to impair the venous outflow from the capillary bed, vasomotion rapidly disappeared. The loss of vasomotion occurred earliest during pentothal and ether anesthesia. In the pentobarbital group, its loss was more gradual. Dogs given morphine did not develop a slowed blood flow to the degree obtained with ether, pentothal, or pentobarbital, and never completely lost their vasomotion. In the control and cyclopropane groups, in which capillary flow remained adequate, an augmented vasomotion persisted throughout.

Epinephrine Reactivity Following Hemorrhage.—An attempt was made to quantitate changes in the peripheral vascular bed during hemorrhage by studying the response of its muscular components to minimal concentrations of epinephrine. During hemorrhage the peripheral muscular components reacted to progressively smaller concentrations of epinephrine, topically applied. The increased reactivity was evidenced both by a response to extremely low dilutions and by a longer and more intense constriction. The significant feature, as noted in Fig. 5, was not the actual increment in reactivity to epinephrine but the persistence of this response with increasing blood loss.

In the control group, hemorrhage resulted in a progressive increase in epinephrine reactivity from a concentration of 1 part in 5 million to as high as 1 part in 50 million. Dogs given morphine closely resembled the controls except that their reactivity after hemorrhage increased only sixfold as against tenfold in the controls. Cyclopropane and pentothal brought about the largest proportional increase in reactivity following hemorrhage, despite the fact that the initial values prior to blood loss were two to three times higher than those of the controls. Dogs receiving pentothal showed an abrupt, rapid decrease in their epinephrine response. This occurred soon after maximal blood loss and a marked slowing in capillary flow, as noted in Fig. 3. In contrast, during cyclopropane anesthesia, where capillary blood flow remained adequate, the reactivity was maintained throughout. The ether and pentobarbital groups exhibited a progressive decrease in epinephrine response in the interval after the last bleeding.

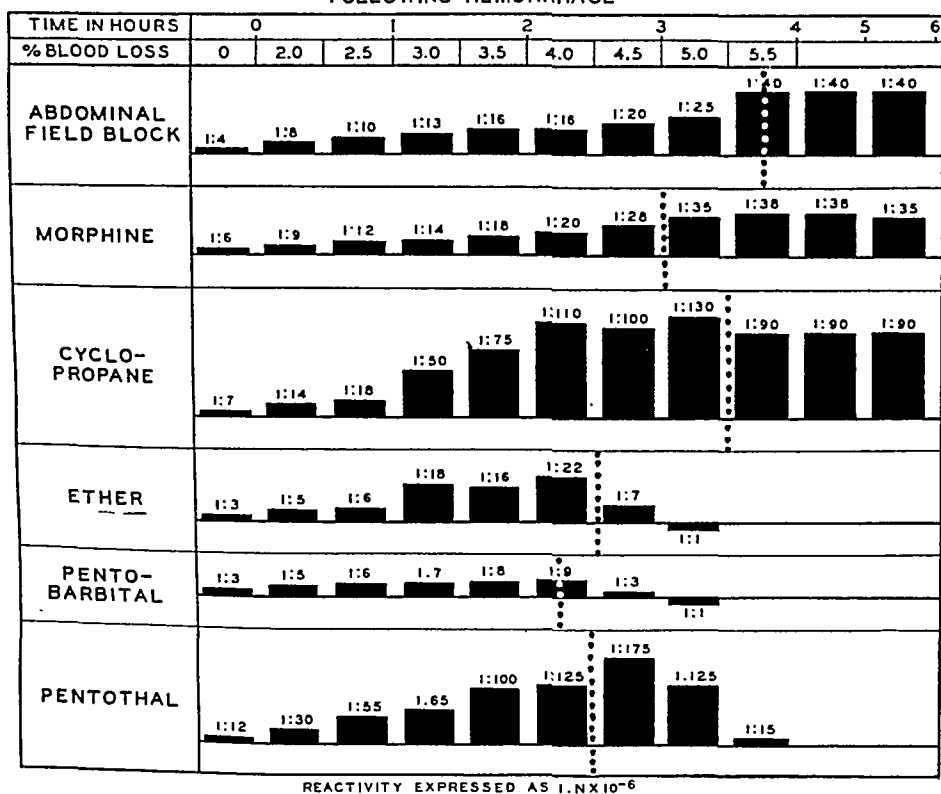
In general, a decreasing epinephrine reactivity occurred in the same animals which showed a decreasing vasomotion, although the two processes did

not closely parallel each other. When both criteria were subnormal, the prognosis for recovery was poor. Infusion at this time resulted in a relaxation of the larger arteries and a passive dilatation of the muscular components of the capillary bed.

Analysis of Blood Samples.—The omental circulatory criteria were correlated with changes in venous oxygen, blood uric acid, and the presence of vasoexcitators and vasodepressors in the blood.

Venous oxygen: The normal values listed in volumes per cent in Table I varied somewhat with the anesthetic procedure, being lowest in the morphine and control groups, which received no oxygen. Therefore, for purposes of comparison, the venous oxygen data were considered as fractions of the normal, rather than as volumes per cent. This procedure was valid since there were no actual differences in any of the other criteria studied referable to the administration of oxygen.

EPINEPHRINE REACTIVITY OF OMENTAL VESSELS
FOLLOWING HEMORRHAGE



REACTIVITY EXPRESSED AS $1:N \times 10^{-6}$

Fig. 5.—Minimal effective concentrations of epinephrine, topically applied, indicated as $1:N \times 10^6$. Dotted vertical lines indicate final bleeding.

In all experiments, regardless of the anesthesia, as hemorrhage increased there was a progressive decrease in venous oxygen until, following maximal blood loss, an abrupt decrease to minimal values occurred. The gradual decrease reduced the oxygen to one-half to one-third its original value, and the ensuing abrupt decline brought it to one-eighth to one-tenth of normal. In actual volumes per cent, these critical values ranged from 1.5 to 3.5. Dogs falling below this level invariably died. The point in the syndrome at which the abrupt fall in venous oxygen occurred, followed by a variable period (ten to forty minutes) the onset of capillary stagnation in the omentum. No evi-

dent relationship was found between the level of venous oxygen and the deterioration of vasomotion and epinephrine reactivity.

Blood uric acid: As noted in Table I, the normal uric acid values in all experiments ranged from 0.8 to 2.1 mg. per cent. The highest values were obtained during pentobarbital anesthesia, in which the uric acid increased from 1.0 to 4.5 to 4.7 mg. per cent, a four- to fivefold increase. In all other groups, the uric acid levels increased two- or threefold, reaching 2.4 to 3.5 mg. per cent following hemorrhage. As a rule, the largest proportionate increase in uric acid was obtained in those animals which became refractory to transfusion, that is, those given pentothal, pentobarbital, and ether. The smallest

ANALYSIS OF BLOOD SAMPLES FOLLOWING HEMORRHAGE

TIME IN HOURS	0		1		2		3		4		5		6	
% BLOOD LOSS	0	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5					
	ABDOMINAL BLOCK													
RAT TEST	V A S O E X C I T O R													
URIC ACID(MG.%)	1.2	—	1.6	—	2.0	—	2.1	—	2.0	—				
	MORPHINE													
RAT TEST	V A S O E X C I T O R							N E U T R A L						
URIC ACID(MG.%)	0.8	—	1.4	—	1.8	1.9	—	—	2.1	—	—			
	CYCLOPROPANE													
RAT TEST	V A S O E X C I T O R													
URIC ACID(MG.%)	0.9	—	—	1.0	1.2	—	1.2	—	—	1.1	—			
	ETHER													
RAT TEST	V A S O E X C I T O R				V A S O D E P R E S S O R									
URIC ACID(MG.%)	0.8	—	—	2.5	—	2.9	—	3.8						
	PENTOBARBITAL													
RAT TEST	V A S O E X C I T O R					V A S O D E P R E S S O R								
URIC ACID(MG.%)	1.2	—	2.1	—	3.3	—	4.1	—	4.5	—				
	PENTOTHAL													
RAT TEST	V A S O E X C I T O R					V A S O D E P R E S S O R								
URIC ACID(MG.%)	1.0	—	1.2	—	1.4	—	—	2.3	—					

Fig. 6.—Presence of vasoexcitor and vasodepressor substances in blood samples. Blood uric acid values are average figures.

relative increase occurred in the cyclopropane and control groups. Dogs receiving morphine showed an intermediate increase in blood uric acid values. It should be noted that blood uric acid levels rose most in those instances in which the omental circulation was poorest, increasing progressively as peripheral blood flow slowed. The only positive correlation between blood uric acid levels and other criteria studied was found to exist in dogs whose blood samples exhibited vasodepressor properties. As indicated in Fig. 6, such dogs invariably showed the highest uric acid levels.

1. *Rat Mesoappendix Test for Vasoexcitors and Vasodepressors in Blood.*—In conjunction with a previous general study of changes in the peripheral circulation in the shock syndrome, a test was devised for the detection of reactive

substances in the blood stream.⁵ This earlier study revealed the presence of "toxic" substances in the blood of dogs subjected, during morphine or pentobarbital anesthesia, to hemorrhage graded so as to induce a state in which the animal became irreversible to infusions of previously lost blood. The rat mesoappendix test was performed by the intravenous injection of 0.5 c.c. of heparinized plasma or serum derived from blood samples, removed at intervals during the experiment. Samples from unbled dogs had no effect on the capillary circulation of the rat mesoappendix other than a transient speeding of blood flow. Samples withdrawn after hemorrhage reproduced in the circulation of the test rat changes similar to those observed in the omentum of the shocked dog. Vasoexcitor substances were associated with the initial blood loss and vasodepressors appeared when the omental circulation evidenced deterioration.⁵

Similar tests on the rat mesoappendix were performed in this series (Fig. 6). When injected into the test rat, blood samples from animals in the control group gave vasoexcitor responses in the mesoappendix. This effect appeared soon after the first bleeding, and persisted throughout the experiment. No vasodepressor response was obtained, even in the three dogs that died. The rat mesoappendix responded in essentially the same manner to blood samples from dogs given cyclopropane. In the morphine group, vasoexcitor responses were elicited by samples taken shortly after initial blood loss. This type of reaction was obtained until the blood loss reached 3.5 per cent, after which the blood samples became nonreactive or neutral. In the previously reported study,⁵ vasodepressors did appear in the blood of dogs given morphine, after they had been maintained in extreme hypotension (40 to 45 mm.) by support with repeated small infusions. Results in the pentobarbital groups were essentially the same as previously reported. Vasodepressors appeared within forty-five to ninety minutes after maximal blood loss was reached. Dogs during ether anesthesia showed the earliest appearance of vasodepressor in the blood, fifteen to twenty minutes after a 2.5 to 3.0 per cent blood loss. Samples from dogs receiving pentothal elicited the most pronounced vasoexcitor response. Vasodepressor reactions appeared suddenly after the hemorrhage had reached 3.5 per cent. As a result, blood samples taken thirty to forty minutes after maximal blood loss showed the presence of both vasoexcitors and vasodepressors. In instances where pentothal animals did not collapse until two hours after maximal blood loss, blood samples taken just prior to collapse produced only vasodepressor responses. In general, it was observed that vasodepressors appeared in the blood about the time that the omental circulation began to deteriorate.

DISCUSSION

An adequate evaluation of the factors operating in the shock syndrome must of necessity take into account the changes introduced by anesthesia, a hitherto neglected variable. This is especially true in comparing data of experiments carried out during different types of anesthesia. Even though a considerable portion of the experimental work in general has been on animals receiving barbiturate anesthesia, standardization is not possible since the barbiturates differ in their pharmacologic action, in the duration of their activity, and in the site and rate of detoxification. Previous attempts to evaluate the influence of certain anesthetic agents in shock^{9, 14-17} did not use criteria which were sufficiently accurate indices of the progressive nature of the syndrome,

This feature has been overcome, to a considerable degree, in the present study by the utilization of characteristic changes in the activity of the capillary bed, a portion of the vascular tree directly involved in the circulatory collapse.

The present study has shown that dogs subjected to a controllable and standardized type of hemorrhage present well-defined differences in their circulatory reactions, depending upon the anesthetic agent used. Objective evidence for this was obtained by employing the peripheral circulation of the omentum as a criterion. Had emphasis been placed solely on the other criteria presented, clear-cut evidence would not have been available until the terminal phases of the syndrome had been reached.

Omental blood flow was the single criterion which could be used by itself to evaluate the general status of the animal at any stage in the syndrome. The rate of flow alone provided an excellent visual prognostic guide. In addition, a critical estimate of the basic features underlying peripheral circulatory failure was obtained by recording changes in the functional integrity of peripheral vascular mechanisms. These mechanisms include vasomotion, reactivity of the muscular elements, patterns of distribution of blood flow through the capillary bed, degree of constriction in the arteries feeding the bed, state of tone of the venous vessels, and adequacy of the venous outflow from the bed.

As a basis for comparing the influence of different anesthetic agents, use was made of the circulatory changes in animals regarded as unanesthetized controls, their only anesthesia consisting of local infiltration of procaine. These changes were remarkably uniform and proved to be an especially satisfactory set of controls. Bleeding, in these animals, resulted in a compensatory vasoconstriction of the larger omental arteries and the development of increased vasomotion in the capillary bed. This hyper-reactive state persisted for a period of five to six hours, at which time the dogs were sacrificed.

Each of the anesthetic agents investigated produced variations from the controls in one or more of the criteria studied. Cyclopropane produced the least change in the peripheral circulatory dynamics. In addition, it was the only anesthetic agent which resembled the controls in maintaining a high level of peripheral compensatory reactivity throughout. It was significant that the controls and those receiving cyclopropane gave evidence of the least decrease in the efficiency of the peripheral circulation, showed the lowest experimental mortality, had the longest survival time, tolerated greatest hemorrhage, and responded best to replacement of lost blood.

Evans¹⁸ in a recent publication states that the preferred anesthesia in shock is local procaine block or cyclopropane. An experimental study on dogs (using a thermocouple flowmeter) by Bennett, Bassett, and Beecher⁴ found, on a basis of changes in flow and blood pressure in the major blood vessels, that cyclopropane offered a wider margin of safety after hemorrhage than evipal or ether. The present study has presented further objective evidence for the value of cyclopropane anesthesia in hemorrhage by demonstrating that, of all the anesthetic agents used, it produces the least deleterious change in the peripheral circulation.

Morphine, in the dose used, produced sedation but not complete anesthesia. This small dose brought about circulatory changes differing from those of the controls, especially a gradual decrease in capillary blood flow as maximal blood loss was attained. Although most of the morphine group was reversible to transfusion, the condition of the circulation at the end of the experiment was poorer than that of the controls. Blalock¹⁹ offered evidence that unanes-

thetized dogs and those receiving 1 mg. per kilogram of morphine sulfate had similar bleeding volumes. In the present study, dogs receiving morphine (2 mg. per kilogram) resembled the controls only prior to hemorrhage and during moderate bleeding (< 3 per cent). When the dogs were bled more severely and maintained in extreme hypotension for an extended period (> 4 hours) they showed significant variations from the controls.

The barbiturates and ether were least satisfactory from several points of view. The dogs receiving these drugs uniformly showed a markedly reduced blood flow as bleeding progressed. In addition to the mechanical slowing of flow through the omentum, they showed a deterioration in the functional activity of the capillary bed. Such changes occurred while blood pressures were still relatively high. Dogs given ether or a barbiturate tolerated the least blood loss, had the shortest survival time, the greatest experimental mortality, and the poorest response to transfusion. Furthermore, they were the only groups to show the presence of vasodepressors in the blood, a feature previously reported to be associated with irreversibility to transfusion.⁸

Seeley, Essex, and Mann,¹⁵ Kendrick,¹⁶ Beecher, McCarrell, and Evans,⁹ and Pender and Essex,¹⁷ in studies of shock time, death time, and hemoconcentration during anesthesia with various barbiturates and ether, pointed out that the barbiturates were less deleterious than ether. The differences induced by various anesthetic agents, as established in the present study, confirm the observations of these authors on the barbiturates and ether. However, the present data indicate that, relative to the six anesthetic procedures studied, the effects of the barbiturates on the peripheral circulation do not compare favorably with local, cyclopropane, or morphine anesthesia.

In view of the marked differences introduced by the various anesthetic procedures, it was especially noteworthy that changes in blood pressure showed such poor correlation with any of the other criteria. The hazard of employing blood pressure levels as an index of the condition of the animal was further emphasized by the wide discrepancy between the critical blood pressure levels with different types of anesthesia. Blood pressures of 80 to 85 mm. in the control, cyclopropane, and morphine groups were associated with a good peripheral circulation and comparatively healthy state of the dogs, while the same blood pressure range in the pentothal and ether groups was associated with poor peripheral circulation and incipient collapse. Moon and associates²⁰ used a depressed mean blood pressure of 70 mm. to indicate the onset of shock. Beecher, McCarrell, and Evans,⁹ in their report on the influence of anesthesia on experimentally induced hemorrhage in dogs, likewise used blood pressures of 70 mm. or below to designate the onset of shock. In the present study, this level corresponded to the critical blood pressure level of the ether group. With pentobarbital, a blood pressure of 70 mm. indicated a shock state in only a small percentage of the animals. Furthermore, as has been pointed out, in dogs subjected to procaine (local), cyclopropane, or morphine this blood pressure level did not indicate a shocked state.

The present experiments, by avoiding the introduction of many uncontrollable factors, sharply brought out the differences that could be attributed to anesthetic agents alone. Traumatic methods are difficult to control and to standardize because of the multiplicity of factors involved. On the other hand, hemorrhage, carefully guided by simultaneous observations of peripheral blood flow, provided a sensitive test method for evaluating both the shock syndrome and the effects due to anesthesia.

Pender and Essex¹⁷ reported a comparative study of traumatic shock during ether, pentobarbital, and pentothal anesthesia. Their results, based on hemoconcentration, blood pressure, and survival time, indicate that pentobarbital is least deleterious, pentothal next, and ether considerably the worst. In the present study, with blood loss up to 3 per cent of the body weight, dogs receiving pentothal favorably resembled the controls, except for an early depression of vasomotion. With a more severe hemorrhage, however, these dogs showed a rapid deterioration of the peripheral circulation as marked as that of dogs receiving ether. Both these groups ultimately showed the severest disruption of the peripheral circulation and proved to be the most difficult to recover with transfusion. Although dogs in the ether group showed circulatory disturbances earlier, they did not deteriorate as rapidly as dogs in the pentobarbital or pentothal groups. Terminally, there was little difference among these three anesthetic procedures.

Beecher, McCarrell, and Evans⁹ and Pender and Essex¹⁷ pointed out that the administration of oxygen throughout their experiments resulted in no obvious differences between dogs which received oxygen and those which did not. Findings in the present study demonstrate no differences in the circulatory criteria after blood loss, although the administration of oxygen considerably elevated venous oxygen content.

Use of the described bleeding technique resulted in the spontaneous collapse of a definite percentage of dogs in each group. The majority of the dogs subjected to ether, pentobarbital, and pentothal anesthesia collapsed spontaneously within five to six hours. Their collapse was accompanied by a profound alteration of the peripheral circulation and by the appearance of vasodepressors in the blood. The lowest mortality occurred in the control and cyclopropane series. Mortality was slightly higher with morphine. All of these deaths occurred abruptly, with no previous disruption of the omental circulation and with no evidence of vasodepressor substances in the blood. It is therefore suggested that the barbiturates and ether predispose the dogs to circulatory collapse which may be due to the introduction into the blood stream of vasodepressor substances that interfere with the normal functional activity of the muscular components of the capillary bed.

SUMMARY

Peripheral circulatory studies were made on dogs subjected to a standardized bleeding procedure during six different anesthetic procedures: procaine (local infiltration), morphine sulfate, cyclopropane, ether, pentobarbital, pentothal.

1. *Blood Loss*.—Dogs subjected to local or cyclopropane anesthesia tolerated the greatest blood loss. Those given barbiturates withstood the least.

2. *Blood Pressure*.—Blood pressure levels following equivalent blood loss differed considerably with each anesthetic agent and were found to be the least reliable of the circulatory criteria used.

3. *Blood Flow*.—Blood flow reflected most accurately the general condition of the animal. The most efficient blood flow after hemorrhage occurred in dogs subjected to local or cyclopropane anesthesia. Dogs given ether showed the poorest blood flow after hemorrhage.

4. *Vasomotion*.—After hemorrhage, vasomotion, a functional aspect of the peripheral circulation, was maintained in an augmented state in dogs given procaine, cyclopropane, or morphine. It was depressed by pentothal and ether.

5. *Epinephrine Reactivity*.—Dogs receiving local or cyclopropane anesthesia maintained the hyper-reactivity which developed after the initial bleeding. With the other anesthetic agents the epinephrine response became subnormal, dogs given pentobarbital, morphine, and ether showing a gradual decrement and those given pentothal an abrupt fall.

6. *Venous Oxygen*.—Venous oxygen fell in all the cases.

7. *Blood Uric Acid*.—Blood uric acid showed a gradual increment in all instances, being greatest in those dogs irreversible to transfusion.

8. *Rat Mesappendix Test*.—Vasodepressors were found after hemorrhage in the blood of dogs given ether, pentobarbital, and pentothal.

CONCLUSION

The peripheral circulatory dynamics in dogs subjected to cyclopropane anesthesia were found to approach most closely those of controls receiving local anesthesia. The use of barbiturates and of ether resulted in marked deviations from the controls and the development of a state refractory to blood replacement therapy.

We are indebted to Mr. L. Dzlorney for his valuable technical assistance.

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PULSION DIVERTICULUM OF THE HYPOPHARYNX AT THE PHARYNGO-ESOPHAGEAL JUNCTION

SURGICAL TREATMENT IN 140 CASES*

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THE occurrence of a diverticulum at the pharyngo-esophageal junction which obstructed deglutition was first observed by Ludlow¹ in 1767. Since that time this condition has been of considerable general interest to anatomists, physiologists, clinicians and roentgenologists, and particularly to surgeons, since operative treatment is the only treatment that will correct the condition and relieve its symptoms.

A diverticulum can occur in any part of the pharynx and esophagus. Since Rokitansky's² description of traction diverticula in 1840, they have been classified into two general types: pulsion diverticula and traction diverticula. Pulsion diverticula are most commonly situated in the hypopharynx close to the junction of the pharynx and the esophagus and are often termed "pharyngo-esophageal diverticula." This term probably is incorrect from a strictly anatomic standpoint, for two reasons: (1) Since this abnormality rarely has a muscular coat, it is not a true diverticulum and may be more correctly termed a "sacculation." (2) It is essentially a herniation of the mucous membrane through the muscular wall of the pharynx and not through the wall of the esophagus. However, since the site is close to the pharyngo-esophageal junction and since most of the symptoms are referable to the esophagus, the term "pharyngo-esophageal diverticulum" is very descriptive. The term "pharyngeal diverticulum" should be reserved for those rare lesions that occur in other parts of the pharynx. Pulsion diverticula also occasionally develop in the lower esophagus just above the diaphragm. The diverticulum that occurs most frequently in the esophagus, however, is the traction type and its most common site is the middle third of the esophagus. Esophageal diverticula will not be considered in this paper.

The site of origin of pulsion diverticula at the pharyngo-esophageal junction has been the subject of much discussion and considerable difference of opinion as to whether they originate in one or more regions. Maes and McFetridge³ stated that they always occur at the same point in the posterior wall of the pharynx directly back of the cricoid cartilage at the junction of the pharynx and the esophagus. Lahey⁴ stated that they occur at two points through the mid-posterior wall of the pharynx: (1) through a region beneath the lowest fibers of the inferior constrictor muscle and (2) at the pharyngo-esophageal dimple, the defect in the posterior wall where the cricopharyngeus muscles diverge from the lowest fibers of the inferior constrictor muscle. Shallow⁵ gave three sites of origin, the first being the most common: (1) the commonly described area above the cricopharyngeus muscle either on the right or left side, more frequently on the left, (2) the Killian-Jamison region on the posterolateral wall of the pharynx below the cricopharyngeus muscle and above the circular fibers of the esophagus, and (3) through the lower portion of the inferior constrictor muscle.

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I have had the opportunity of studying six specimens removed at necropsy in cases in which the patients died of other causes. The opening in three instances was through a defect in the left posterolateral wall of the pharynx between the inferior constrictor and cricopharyngeus muscles. In one instance the opening was in a similar position on the right side and in two the opening was posterior through the lower fibers of the cricopharyngeus muscle above the esophagus. Three of these specimens, each showing one of the three different sites of origin of the diverticulum, are shown in Fig. 1.

Determination at operation of the exact site of origin of a diverticulum passing through the muscular wall of the pharynx often is difficult, particularly if the diverticulum is large and has a large opening. However, the origin of smaller ones can be established fairly accurately. In the 140 cases in which I have operated, diverticula were found in four different regions in the posterior

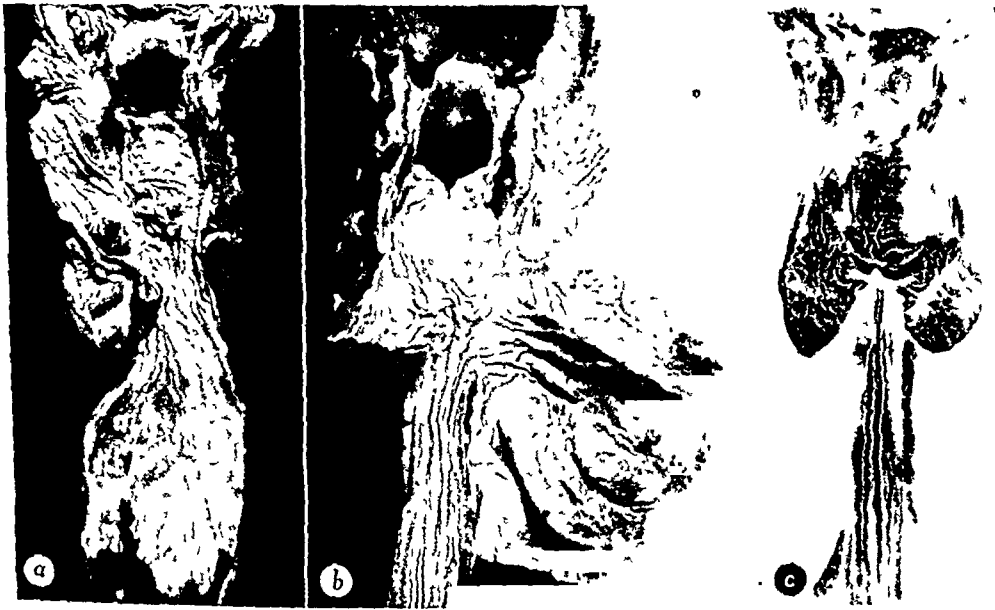


Fig. 1—*a*, Diverticulum originating from the left posterolateral wall of the pharynx with the opening between the inferior constrictor and the cricopharyngeus muscle. *b*, Diverticulum originating from the right posterolateral wall of the pharynx with the opening between the inferior constrictor and the cricopharyngeus muscle. *c*, Median type of diverticulum originating from the posterior wall of the pharynx between the inferior constrictor and the cricopharyngeus muscle.

and lateral pharyngeal walls, as follows: (1) left posterolateral wall between the inferior constrictor and cricopharyngeus muscles, (2) right posterolateral wall between the inferior constrictor and cricopharyngeus muscles, (3) midline, posterior wall, beneath the median raphe of the inferior constrictor muscle and above the cricopharyngeus muscle, and (4) midline, posterior wall, through or immediately beneath the cricopharyngeus muscle above the esophagus (Figs. 2, 3, and 4).

In one case in this series there were two diverticula. One, which was of moderate size, originated from the left posterolateral wall between the inferior constrictor and cricopharyngeus muscles, and the other, a smaller diverticulum, originated from the right posterolateral wall of the pharynx.

There is considerable difference of opinion as to the cause of pharyngo-esophageal diverticula.

Their fairly constant location suggests congenital origin, although they usually do not occur in more than one member of a family. In the 140 cases

in which I have operated, a diverticulum in another member of the family was noted only twice. In one instance the patients were mother and son, and in the other, father and son.

The uniform relationship of the cricopharyngeus muscle to the site of herniation suggests that some congenital malformation of the attachments of this muscle may be a causative factor. The cricopharyngeus muscle, which is attached to the cricoid cartilage anteriorly by an elastic aponeurosis, is the chief closing muscle of the esophageal opening. If some malformation of this muscle exists, it may perform its function satisfactorily during early life. However, the elastic tissue attachments weaken with abnormal stress and atrophy of increasing years, and a herniation may develop as the result of constant and increasing pressure on this congenitally weak region. The foregoing theory was suggested by the average age of patients of this series, which is 57 years.

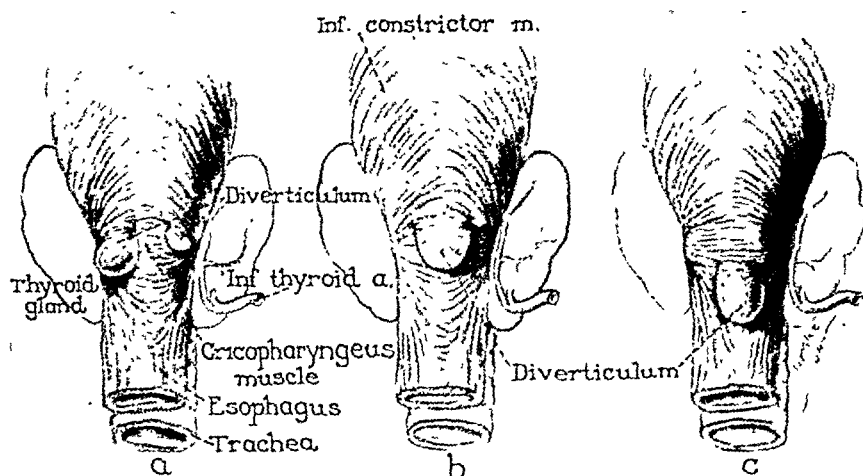


Fig. 2.—Four sites of origin of pharyngo-esophageal diverticula as found at operation: (1) left posterolateral wall between the inferior constrictor and the cricopharyngeus muscle; (2) right posterolateral wall between the inferior constrictor and the cricopharyngeus muscle (1 and 2 shown in *a*); (3) midline, posterior wall, beneath the median raphe of the inferior constrictor muscle and above the cricopharyngeus muscle (shown in *b*); (4) midline, posterior wall, through or immediately beneath the cricopharyngeus muscle above the esophagus (shown in *c*).

In respect to the average age of patients and cause, pharyngo-esophageal diverticula are somewhat analogous to diaphragmatic hernias through the esophageal hiatus. The average age of patients who have a diaphragmatic hernia through the esophageal hiatus is 55 years. These hernias may be caused by atrophy of the diaphragmatico-esophageal membrane which is an elastic tissue aponeurosis that compensates for a congenitally large esophageal hiatus until it atrophies from increasing age and stress.

Many other theories have been advanced to explain the cause of pharyngo-esophageal diverticula. These theories include neuromuscular in-co-ordination during the act of swallowing; a physiologic basis, that is, increased pressure on the posterior wall of the pharynx; and muscular deficiency at the points of entrance of nerves and blood and lymphatic vessels through the muscles of the posterior wall of the pharynx. It is probable that muscular deficiency is the predisposing cause and that other factors are the inciting element. This would tend to explain why the symptoms are progressive and usually do not present definite form until the patient has reached middle age.

In this series of 140 cases, 107 patients were men and 33 were women. The ages of the patients varied greatly, the oldest being 80 years of age and the youngest being 34. The average age was 57 years. Seven patients were between



Fig. 3.—*a*, Two diverticula, one from the left and one from the right posterior wall of pharynx. The left diverticulum, which originated between the inferior constrictor and the cricopharyngeus muscle, was removed by a one-stage operation through a left cervical approach. The small diverticulum on the right was not removed. *b*, Diverticulum in the right posterolateral wall, originating between the inferior constrictor and the cricopharyngeus muscle, removed by one-stage diverticulectomy through right cervical approach.



Fig. 4.—*a*, Large median diverticulum originating beneath the median raphe of the inferior constrictor muscle posteriorly, removed by one-stage diverticulectomy through left cervical approach. *b*, Large median type diverticulum extending into mediastinum and originating through the lower fibers of the cricopharyngeus muscle above the esophagus, removed by one-stage diverticulectomy through left cervical approach.

the ages of 30 and 39 years; twenty-five between 40 and 49 years; fifty-seven between 50 and 59 years; thirty-eight between 60 and 69 years; eleven between 70 and 79 years, and two patients were 80 years of age.

CLINICAL MANIFESTATIONS

The clinical manifestations of pharyngo-esophageal diverticula vary as to type, duration, progress, and severity. The symptoms are progressive, depending on the type of sacculation as well as on the rapidity with which it increases in size (Fig. 5).

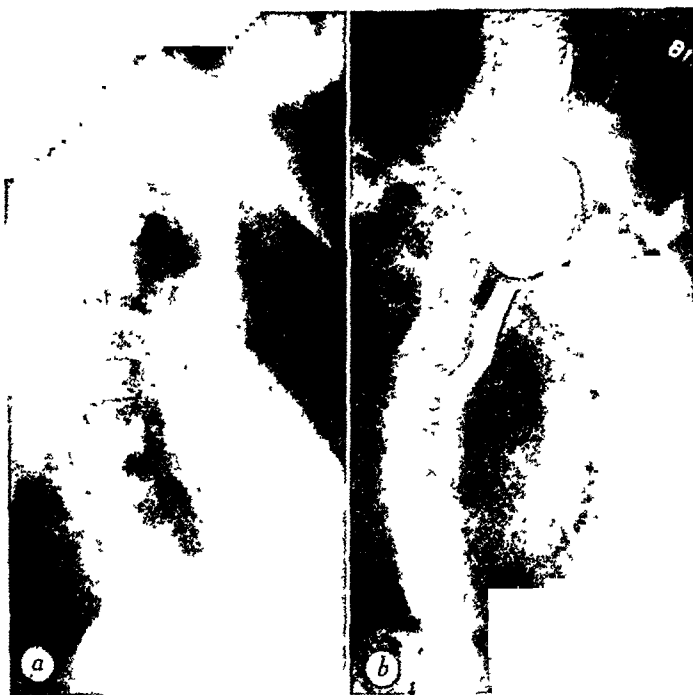


Fig. 5—Progressive development of pharyngo-esophageal diverticulum. *a*, First admission, 1927: moderate-sized diverticulum causing moderate symptoms. Patient refused operation. *b*, Second admission, 1936: diverticulum had increased about three times in size in the intervening nine years, causing symptoms of retention of food and partial obstruction of the esophagus. Patient consented to operation.

In 80 per cent of the 140 cases in this series the symptoms were vague and indefinite at onset and were slowly progressive. In 20 per cent of cases the symptoms were more rapid in progress and severity. The duration of symptoms was from one to twenty-five years, the average duration before operation being approximately five years. This difference in the rate of progress of symptoms is more related to the character of the neck than to the size of the sac. In many instances a relatively small diverticulum which has a small opening produces disabling symptoms, whereas a large diverticulum which has a large opening produces relatively little distress and disability because the contents of the sac can be more easily emptied. However, regardless of the size of the opening, the severity of the symptoms increases with the size of the diverticulum, particularly after it becomes large enough to retain food and secretions. Ultimately, complete esophageal obstruction may result. In this series, fifteen patients had marked obstruction and three had complete obstruction at the time of admission to the clinic. In one of the latter patients, it was necessary to perform a preliminary gastrostomy for feeding but in the others it was possible to pass an indwelling stomach tube for preoperative feeding (Figs. 6 and 7).

The earliest symptom usually is dysphagia. There is a sensation of a foreign body obstructing the normal process of swallowing and food seems to stick in the

throat. Later, food and mucus are regurgitated. These symptoms do not occur until a definite sacculation is formed. Noisy deglutition and gurgling sounds in the throat, which result from the swallowing of air and the accumulation of food and mucus in the sac, often occur. If there is difficulty in regurgitating the food, pressure on the side of the neck will often aid in emptying the sac.

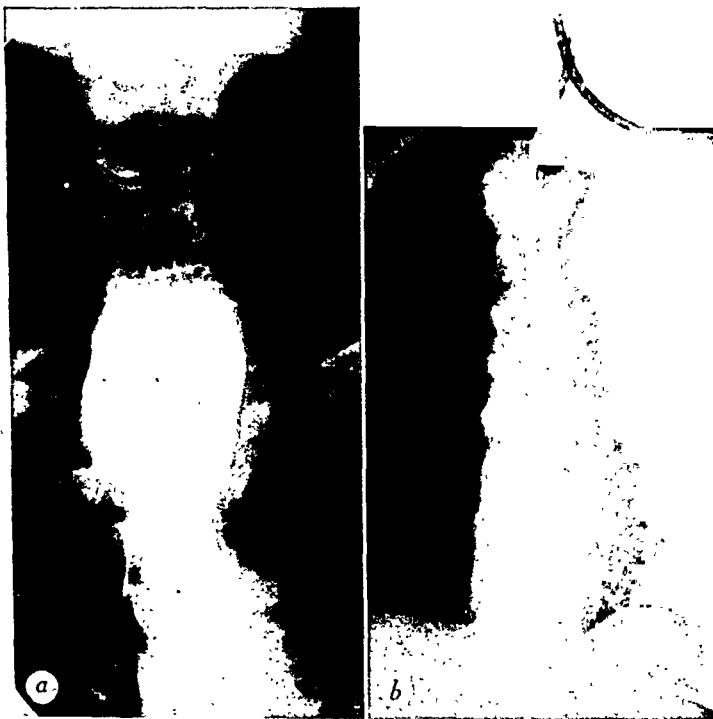


Fig. 6.—Pharyngo-esophageal diverticulum, median type, originating below the crico-pharyngeus muscle, causing complete obstruction. Patient 80 years of age. Weight loss twenty-five pounds (11 kg.). *a*, Diverticulum extending into mid-mediastinum. *b*, Three days later, after introduction of indwelling stomach tube for feeding; residual barium in diverticulum.



Fig. 7.—*a* and *b*. Nineteen days after one-stage diverticulectomy. Left cervical approach; esophagus normal, incision healed.

After the sac has become well developed, its enlargement is more rapid than before because of the increased pressure from within, which is caused by the more or less constant retention of food and secretions. The sac pushes downward and backward, between the prevertebral and the pretracheal fascia, into the mediastinum, and may extend to the arch of the aorta. Progressive esophageal obstruction often occurs because the enlarging opening of the diverticulum is pulled downward and forward and obstructs the normal esophageal orifice. This orifice, which often becomes a narrow slit, may be pushed laterally. The portion of the upper part of the esophagus that is in apposition to the diverticulum is flattened and distorted by direct pressure of the body of the sac. Food enters the diverticulum first and then overflows into the esophagus. Patients often spend hours at their meals in order to obtain enough nourishment to sustain life. The loss of weight may be great, one patient in this series having lost 100 pounds (45.4 kg.) before admission to the clinic.

The largest sac found in this series filled the entire superior mediastinum and extended into the right thoracic cavity. After its removal it held 825 c.c. of fluid. This patient had had symptoms for fifteen years. For the last year he had had marked retention of food in the diverticulum with increasing difficulty in taking solid food. His diet had consisted chiefly of milk. Before he could get any food into the esophagus, he had to drink more than one pint of milk. He reported that he ate and regurgitated food three or four times at a meal before he was successful in getting any appreciable amount of food into the esophagus. He had lost twenty-five pounds in the last three months.

When a large sac that extends into the mediastinum is filled with food it produces marked pressure on the adjacent intrathoracic organs and causes a distressing sensation of fullness in the thorax, which often is associated with dyspnea, palpitation of the heart, and a sense of suffocation. Severe cough and choking spells frequently occur. Many times patients lower their heads, as is customary in postural drainage, and then press on the side of the neck in order to empty the sac. In some instances food may enter the trachea and cause marked cyanosis.

Repeated aspiration of food into the bronchi may result in bronchitis or bronchiectasis. In this series of 140 cases, bronchitis was present in nine cases, and bronchiectasis in four. Associated hoarseness of the voice also occurs. This is caused by pressure or inflammatory reaction around the recurrent laryngeal nerve, which is often close to the neck of the sac. In this series of cases, hoarseness was present in eight cases; the vocal cord was fixed in two cases.

After the sac has become definitely formed, the symptoms are definite and characteristic. The diagnosis usually can be made on the basis of the symptoms, but it should be proved by roentgenographic examination. In the earlier stages when the symptoms are vague, a definite clinical diagnosis may not be possible without an esophagoscopy or roentgenologic examination. These methods are the most accurate in the establishment of a definite diagnosis and they should be employed in all cases in which there are any persistent signs of dysphagia. The longer the diagnosis is delayed, the greater is the risk of serious complications which may enhance the difficulties and may impair the results of surgical treatment.

TREATMENT

Although pharyngo-esophageal diverticula first were recognized more than 175 years ago, they were not treated surgically until 1877, about sixty-eight years

ago, when Nicoladoni⁶ produced a cervical fistula by diverticulotomy. This procedure obviously could not effect a cure. Neilans,⁷ in 1884, reputedly was the first surgeon to perform a primary diverticulectomy but the operation was not successful. The first successful operation for the condition was reported by von Bergmann⁸ in 1892. These early operations were associated with a relatively high mortality, chiefly because of mediastinitis, pneumonia, and pulmonary abscess. In many cases in which the patients recovered, the morbidity was great because of a pharyngeal fistula. These complications led to the operation in two stages, which Goldmann,⁹ of Freiburg, is credited with introducing in 1909. This procedure greatly reduced the mortality.

Complete extirpation of the diverticulum by operative measures now is generally accepted as the only method of treatment that will completely relieve the symptoms. There is still some difference of opinion, however, as to whether diverticulectomy should be performed in one stage or in two stages. Both operative procedures are favored by various surgeons of wide experience. Lahey,⁴ in 1940, reported a series of 118 cases in which the two-stage procedure was used. One patient died and three had recurrences that required reoperation. Shallow,⁵ in 1936, reported a series of seventy-nine cases. Seventy-six of these patients underwent a one-stage operation and three, a two-stage operation. There were two operative deaths and two recurrences.

In the 140 cases in which I have operated for pharyngo-esophageal diverticulum, both the one-stage and the two-stage procedures have been employed. This series includes the thirty-three cases which I¹⁰ presented at the Forty-Seventh Annual Meeting of the Western Surgical Association, Dec. 3, 1937. The one-stage operation was performed in eight of the thirty-three cases and the two-stage operation in twenty-five. Since 1937, I have performed the one-stage operation in 107 additional cases. Thus, in this series of 140 cases, the one-stage operative procedure was performed in 115 cases and the two-stage procedure in twenty-five cases.

Complete removal of the sac, including its neck, is generally accepted as the only effectual surgical procedure for pharyngo-esophageal diverticulum. The technical difference in the two operative procedures advocated to accomplish this purpose is in treatment of the sac and the time of its removal. In the one-stage procedure the sac is removed at the primary operation. In the two-stage procedure a temporary diverticulopexy is performed and the sac is removed at a second operation seven to ten days later. The fundamental difference in these two procedures is that in the one-stage operation the fascial planes leading to the mediastinum are not walled off prior to removal of the diverticulum and in the two-stage operation the interval between the operations permits the formation of granulations which wall off the fascial planes of the neck and mediastinum.

Preoperative Considerations.—Patients who have lost considerable weight as a result of their inability to obtain sufficient nourishment require preoperative feeding. In most instances this can be accomplished by an indwelling stomach tube. Sixteen patients in this series of 140 cases were prepared for operation by this means. In one case in which complete obstruction was present it was impossible to pass the stomach tube, and a preliminary gastrostomy was necessary for feeding.

Dilatation of the introitus of the esophagus is advisable and has been performed routinely in the last fifty cases of this series. In many instances the

After the sac has been completely dissected free from the surrounding structures, the true neck of the sac is dissected from the pharyngeal muscles. Particular care is taken to separate and remove any fibers of the inferior constrictor muscle and of the cricopharyngeus muscle above and beneath the neck of the sac, respectively. In many of the larger diverticula, the opening into the pharynx is large and consists essentially of diffuse bulging of the back wall of the pharynx. In this type, great care should be exerted to determine the true relationship of the opening of the sac to the muscular wall of the pharynx, which often is much thinned out. It is important to dissect these diffuse sacculations from the muscle and to establish as small a neck to the sac as possible, being careful not to remove too much of the mucous membrane because of the danger of producing a stricture. After the true neck of the sacculation has been isolated from the surrounding muscles, it is transfixed by the use of chromic catgut and the diverticulum is completely excised. The stump of the sac is then invaginated into the wall of the pharynx and the muscles of the wall which sur-

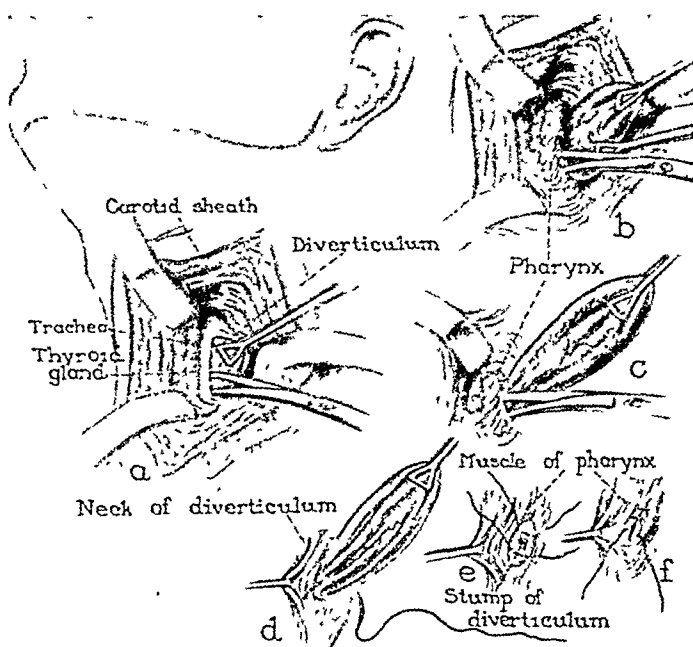


Fig 8—One-stage diverticulectomy. *a*, Incision along the anterior border of the sternocleidomastoid muscle, retracting the thyroid medially and the carotid sheath with the sternocleidomastoid muscle laterally. The peritracheal fascia is incised at the level of the cricoid cartilage, exposing the diverticulum. *b*, Dissecting the diverticulum from the peritracheal fascia and elevating it from the fascial planes, starting at the neck of the sac. *c*, Dissecting the true neck of the sac from the surrounding muscles of the posterior wall of the pharynx. *d*, Transfixing and ligating the neck of the sac with chromic catgut. *e*, Invagination of the stump of the sac into the wall of the pharynx. *f*, Closing the opening in the muscles of the posterior wall of the pharynx with chromic catgut.

rounded the neck of the sac are closed with interrupted catgut sutures. The silk thread which is through the esophagus is pulled taut by the anesthetist before the neck of the sac is ligated so that there is no danger of including it in the closure of the neck of the sac. A soft rubber tissue drain is placed in the pocket formerly occupied by the diverticulum but it is not placed at the site of closure of the pharyngeal wall. The wound is closed by the use of interrupted sutures.

Results of Operation.—In the 115 cases in which the one-stage operation was performed, there were no operative deaths. A temporary pharyngeal fistula developed in five cases. In three cases hoarseness occurred two to three days after operation and subsided within one week to ten days. In one case in which

the patient had hoarseness of the voice before operation, paralysis of the cord occurred and the hoarseness continued. The average duration of convalescence in the hospital was less than two weeks and the average period of time to dismissal was three weeks.

In five cases angulation of the esophagus required dilatation. The diverticula recurred in two cases. In one of these the symptoms improved after dilatation but operation subsequently may be required. In the other case, a second operation was necessary (Figs. 9, 10, 11, and 12). In this case, the diverticulum was infected at the time of the patient's first admission and had produced marked granular pharyngitis and swelling of the mucous membrane which closed the neck of the sac. This infection continued in spite of persistent efforts for three weeks before operation to irrigate the diverticulum and drain the in-

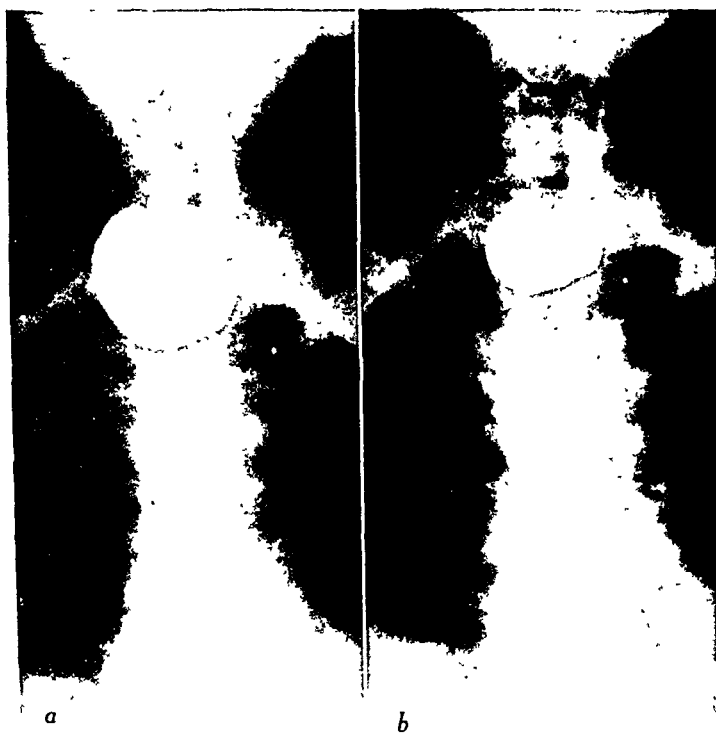


Fig. 9.—*a*, On admission, showing infected pharyngo-esophageal diverticulum extending into the mediastinum, containing several ounces of pus and producing acute pharyngitis. *b*, Four days later, showing residual barium in diverticulum, although patient has had repeated irrigations.

fection. The persistent infection presented a surgical problem; this is the only recent case in which I have considered a two-stage operation. However, a one-stage procedure was performed. Convalescence was satisfactory for ten days. Then a pharyngeal fistula developed and persisted for three weeks. Mediastinitis did not develop and the wound was entirely healed in four weeks. Subsequently a recurrence on the right side of the pharynx, which I believe was caused by weakening of the wall of the pharynx by the infection, occurred. The recurrence was noted on the roentgenogram as somewhat diffuse bulging of the right posterolateral wall of the pharynx. There was no dysphagia, but after a period of three years the patient began to have a gurgling noise and food occasionally stuck in his throat. The sacculization had progressively increased in size and operation was performed through a right cervical approach. The wound was completely healed at the time of dismissal nineteen days after operation.

This case is very instructive from the standpoint of the danger of mediastinitis associated with the one-stage operative procedure when the diverticulum is acutely infected. A pharyngeal fistula developed but there was no extension of infection into the surrounding mediastinal structures. The other four cases in which a temporary pharyngeal fistula occurred showed no signs of medias-

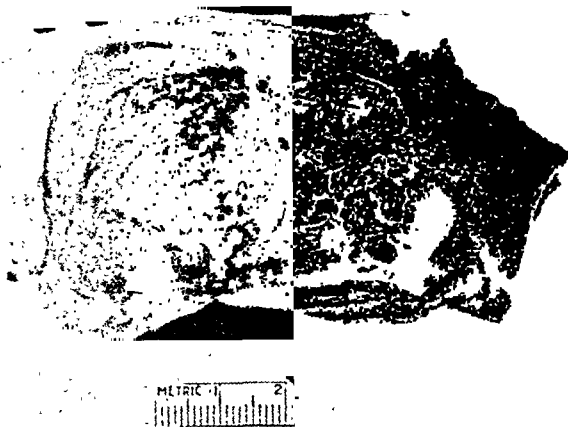


Fig. 10.—Diverticulum after its removal by left one-stage diverticulectomy, showing marked infection with thickening of the walls.



Fig. 11.—Same patient as in Fig. 9. *a*, Ten months after one-stage diverticulectomy through left cervical approach, showing moderate-sized recurrence in right posterolateral pharyngeal wall; no dysphagia. *b*, Three years after diverticulectomy, showing marked increase of the size of the recurring diverticulum in the right posterolateral wall of the pharynx; moderate regurgitation. Patient was treated by dilatations during interval.

tinitis. The earliest that a fistula developed was on the third postoperative day. This patient obtained considerable water the first night after operation without the knowledge of the nurse. Mediastinal infection did not occur, and the fistula healed within a week. The other three fistulas did not develop until after the sixth day and all closed within a week.



Fig 12, *a* and *b*—Same patient as in Figs 9 and 11. Six months after right one-stage diverticulectomy for recurring diverticulum, esophagus normal. Both left and right cervical incisions healed, no symptoms.



Fig 13, *a* and *b*—Large pharyngo-esophageal diverticulum (which held 825 cc of fluid) beneath the inferior constrictor and cricopharyngeus muscles. Median posterior type of diverticulum causing marked obstruction, filling the entire mediastinum and extending into the right side of the thoracic cavity.

I believe there is little risk of mediastinitis occurring after a one-stage operative procedure because in none of my cases has a fistula developed before seventy-two hours after operation. By that time the mediastinal fascial planes are walled off. However, it is important not to separate any more of the tissues of the mediastinal fascial planes than is essential and to remove the diverticulum starting at the neck of the sac.

Fifteen of the 115 patients in this series had large diverticula that filled the entire mediastinum. In several instances they extended into the thoracic cavity. As mentioned previously, the largest one held 825 c.c. of fluid (Figs. 13 and 14). There was no suggestion of mediastinal infection after operation in any of these cases.



Fig. 14. *a* and *b*—Nineteen days after one-stage diverticulectomy, right cervical approach. Esophagus normal except for slight angulation. No symptoms, incision healed.

The results of operation in the twenty-five cases in which a two-stage operation was performed are essentially the same as those reported in 1937 with the exception that one more recurrence has developed. A summary of these twenty-five two-stage operations follows: There was one operative death in the case of a patient who had Parkinson's disease. Although this death was attributed to the operation, it was the result of his poor general condition; the latter was caused by weight loss as a result of his inability to take nourishment because of the diverticulum as well as advanced Parkinson's disease. A temporary fistula developed in six cases. In three cases there was temporary hoarseness and in one case there was paralysis of one vocal cord. The average convalescence before dismissal from the hospital was more than five weeks.

Five patients had angulations that required subsequent dilatations. There were three recurrences, all of which were treated by dilatation. Two patients subsequently may require surgery.

A comparison of the results of the one-stage and the two-stage operations is shown in Table I, and a summary of the clinical data of the entire series of 140 cases as described in the text is shown in Table II.

TABLE I. DIVERTICULECTOMY FOR PHARYNGO-ESOPHAGEAL DIVERTICULUM: 140 CASES
RESULTS OF ONE-STAGE AND TWO-STAGE OPERATIONS

	ONE-STAGE*	TWO-STAGE†
Operative mortality	0	1
Temporary fistula	5	6
Temporary hoarseness	3	3
Paralysis of one vocal cord	1	1
Average convalescence	3 weeks	5+ weeks
Angulation of esophagus that required dilatations	5	5
Recurrences	2	3
Symptoms relieved by dilatations	1	3
Symptoms requiring second operation	1	0

*One-stage operation, 115 cases; marked esophageal obstruction, 15; preliminary gastrostomy, 1.

†Two-stage operation, 25 cases; complete obstruction, 3; indwelling stomach tube, 14.

TABLE II. CLINICAL DATA

Males: 107	Females: 33	Total patients: 140
Average age: 57 years	Youngest: 34 years	Oldest: 80 years
Year: 34-39; 40-49; 50-59; 60-69; 70-79; 80		
Patients:	7 25 57 38 11 2	
Duration of symptoms, 1 to 25 years	Average duration, 5 years	
Multiple diverticula of pharynx, 1 (left side larger than right)		
Occurrence in other member of family, 2		
Associated conditions:		
Bronchiectasis, 4; bronchitis, 9; goiter, 10; hiatal hernia, 3; esophageal diverticulum, 1; hoarseness, 8; fixed vocal cord, 2		

COMMENT

Many factors, such as the condition of the patient and the type of lesion, must be taken into consideration in comparing different types of operative treatment for a surgical condition. These factors being equal, the chief consideration in determining the relative value of different procedures is the operative mortality, its effectiveness in relieving the condition, and the associated morbidity. The results obtained in these two types of operations in this series of 140 cases of pharyngo-esophageal diverticula, I believe, definitely show the value of the one-stage procedure.

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CLOSURE OF THE BRONCHIAL STUMP FOLLOWING LOBECTOMY OR PNEUMONECTOMY

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ANY method of bronchial closure, if it is to be successful, must be based upon the fundamental principles of healing. It is self-evident that there should be the least possible trauma such as crushing of tissue; that there should be accurate approximation of the surfaces which are expected to heal together; and that there should be an adequate blood supply to the tissues involved. Rienhoff and his collaborators* in an excellent article concerning the closure of the bronchus stress these matters and point out that the healing of the bronchus takes place at the cut end of its stump. Granting this premise, it is illogical to use mattress sutures which approximate the mucosal surfaces behind the cut end of the bronchus. No healing can be expected at that level and such sutures are likely to impair the blood supply by pinching off some of the branches of the bronchial artery. Rienhoff and co-workers also emphasize the importance of covering the closed bronchial stump with pleura. On the basis of these fundamental principles, the method which is most likely to succeed should:

1. Produce the least possible trauma at the end of the bronchus
2. Preserve an adequate blood supply all the way to the cut end of the bronchus
3. Approximate only the edges of the cut end of the bronchus
4. Provide adequate reinforcement of the bronchial closure by utilization of a layer of pleura sutured over the closed stump.

The method I have used is as follows. After the lobe (or lung) which is to be removed has been mobilized and the pulmonary vessels which supply it have been tied and divided separately, a large curved clamp such as might be used on the kidney pedicle is applied distal to the level which has been selected for the division of the bronchus. The purpose of this clamp is merely to prevent spilling of pus or secretions from the diseased portion of the lung and also to provide a handle with which to steady the bronchus while it is being cut across (Fig. 1, A). A suture of medium weight silk is then passed through the bronchial wall, tied, and held as a stay. Using a knife which is curved on the flat surface and sharpened on both edges (such as the Beaver blade No. 14), the division of the bronchus proximal to the clamp is started. One or two more silk sutures are then placed over the cut end of the bronchus and the division is completed with the knife. Several more sutures are then placed and all are tied over the end of the bronchial stump so as to approximate its cut edges. While the bronchus is being cut across, the sutures are held tightly by the assistant so as to minimize the escape of anesthetic gases. After all of the sutures have been tied, the stump is inspected for air leakage and one or more sutures are placed as needed.

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*Rienhoff, W. F., Gannon, J., Jr., and Sherman, I.: Closure of the Bronchus following Total Pneumonectomy, *Ann. Surg.* 116: 481-531, 1942.

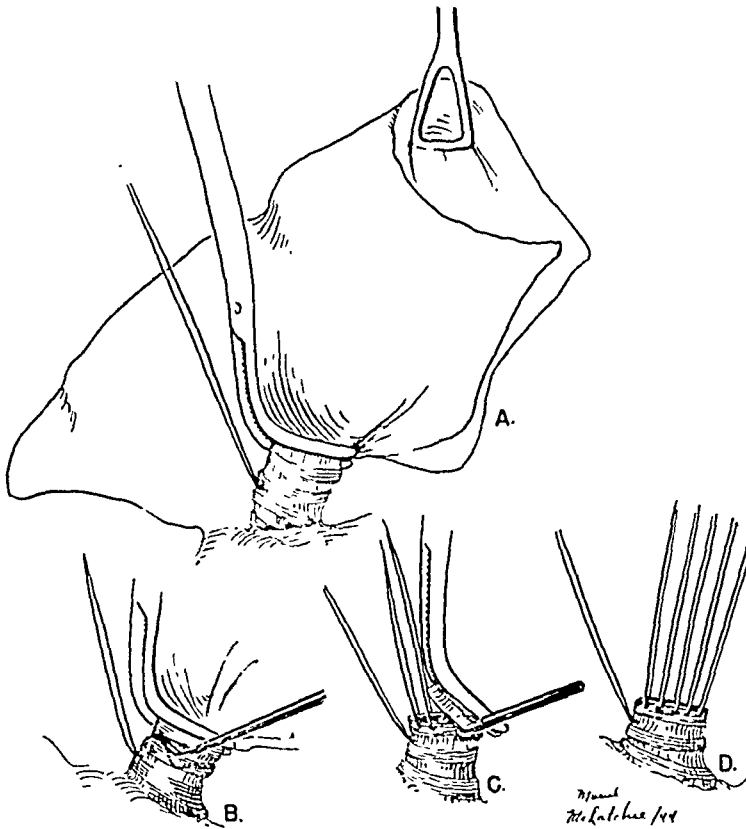


Fig. 1.—Steps in the closure of the bronchial stump. A, Traction suture applied. B, Division of the bronchus begun, using curved knife; note that the bronchus is cut across proximal to the clamp. C, Bronchus partly severed with two sutures applied. D, Division of the bronchus completed with all sutures placed.

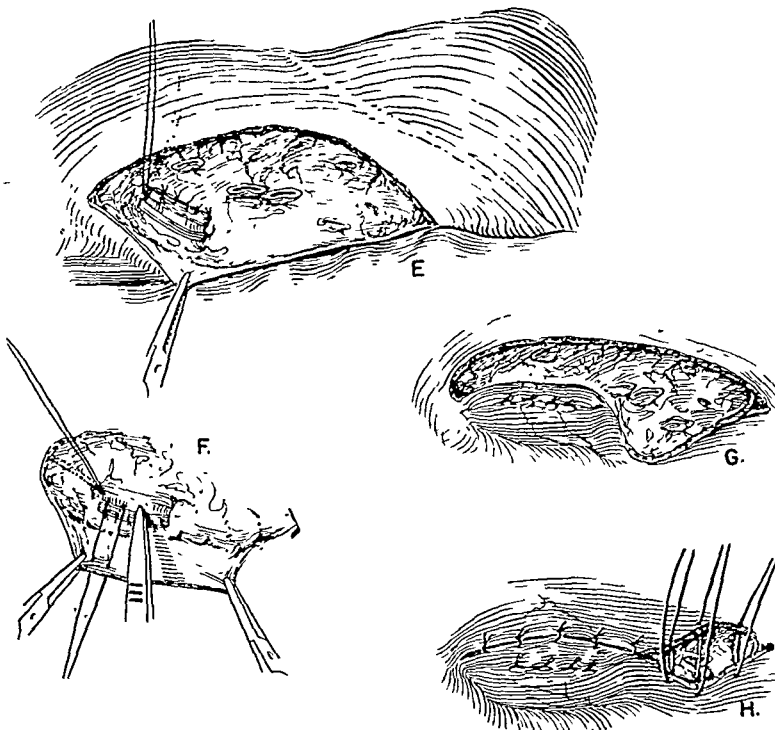


Fig. 2.—Steps in the covering of the bronchial stump. E, Stump after tying all sutures; flap of pleura to be sutured over held in a hemostat. F, First suture placed between pleural flap and side of the bronchial stump. G, All sutures tied, thus covering the end of the stump. H, Additional reinforcement possible in some cases.

There remains the important step of burying the bronchial stump beneath a flap or fold of pleura (Fig. 2). An edge of the mediastinal pleural surface, usually posterior to the region of the hilum of the lung, is almost always available. This edge is pulled over the end of the bronchial stump and fastened to the bronchus proximal to its end by means of several fine silk sutures (Fig. 2, *F* and *G*). If the pleural flap cannot be pulled over the stump easily, the tension can be relaxed by making a linear incision in the pleura several centimeters back from its edge. In many cases it is possible to add reinforcement by overlapping the opposing pleural edge as shown in Fig. 2, *H*.

This method of bronchial closure has been used in approximately 140 cases of lobectomy or pneumonectomy in the past two years. Table I shows the number and types of cases.

TABLE I. TYPES OF CASES IN WHICH THIS METHOD OF BRONCHIAL CLOSURE HAS BEEN USED

DISEASE	OPERATION		TOTAL
	LOBECTOMY	PNEUMONECTOMY	
Bronchiectasis	34	5	39
Lung abscess	22	3	25
Chronic pneumonitis	3	0	3
Tuberculosis	16	27	43
Bronchogenic cyst	1	1	2
Carcinoma	2	22	24
Metastatic carcinoma	2	0	2
Neurofibroma	0	1	1
Fibrosarcoma	0	2	2
Total	80	61	141

Leakage resulting from breaking open of the bronchial stump was known to have occurred in only one of these cases. This was a case of pneumonectomy for tuberculosis in which the primary bronchus was so embedded in calcified and caseous lymph nodes, which produced a stenosis of the bronchus, that a satisfactory closure could not be obtained, chiefly because of the necessity for cutting across diseased tissues in the bronchial wall. This man died as a result of an empyema, and at autopsy the failure of the bronchial closure was discovered. In the majority of all other instances where patients died in the hospital after operation, autopsies were performed and in no case was there any evidence of leakage from the bronchial stump. The postoperative period in these cases varied from a few days to more than two weeks.

As a result, therefore, of a considerable experience with its use, the method of closure of the bronchial stump herein described is proposed as a satisfactory technique for use in the operation of lobectomy or pneumonectomy.

LIGATION OF THE INFERIOR VENA CAVA*

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OCCCLUSION of the renal veins from some progression of a thrombus in the inferior vena cava is usually fatal, although occasional reports to the contrary have appeared infrequently in medical literature.^{1, 2} That pulmonary embolism from such a thrombus may be fatal is well authenticated.

One of us (R. W. B.), with collaborators,³ has reported the utilization of femoral vein ligation in the treatment of chronic deep thrombophlebitis of the lower extremities, and at the time of that report had had occasion to ligate the inferior vena cava, subsequent to femoral vein ligation. This paper is a summary of our experiences to date in ligation of the inferior vena cava for both chronic thrombophlebitis and phlebothrombosis.

Certainly ligation of the inferior vena cava is no longer a novel procedure. The first recorded case of total ligation of the inferior vena cava was reported by Kocher in 1883.⁴ The ligation was done accidentally and unknowingly during the process of dissection of metastatic carcinomatous retroperitoneal lymph nodes. At necropsy a ligature was found about the inferior vena cava. The second recorded case was reported by Billroth in 1885.⁴ The vena cava was mistaken for a distended renal vein and was ligated. The patient died within one hour. The third recorded case of total ligation is that by Bottini,⁵ reported in 1893. This is the first case of successful ligation, the patient making a complete recovery without circulatory complications. Since this time, a large number of reported cases has been added to the literature and Krotzki,⁶ in 1937, was able to collect forty-eight cases of total ligation of the inferior vena cava carried out by twenty-seven operators. Undoubtedly there have been many more caval ligations done since this report.

The earliest cases,⁷ and by far the majority, were those in which accidental injury of the vena cava necessitated complete ligation of this vessel. Most of these injuries occurred during operations upon the kidney. The second largest group of cases were those in which the ligation was done during the treatment of puerperal pyemia.⁸ The earliest caval ligations in this second group were three done by Trendelenburg,^{8, 9} two in 1906 and a third in 1910. The first two patients died shortly after operation, while the third recovered. In more recent years, our attention has been focused upon the quiet thromboses occurring in the lower extremities, and removal of the thrombus followed by ligation of the major venous trunk has been the procedure of choice in most instances. Where bilateral involvement has occurred and rapid progression of the thrombotic process is present, ligation of the common femoral vein preceded by aspiration of the thrombus may be insufficient and ligation at a higher level may be deemed necessary. Where the involvement is bilateral, ligation of the inferior vena cava is often preferable to bilateral ligation of the external or common iliac veins. The high mortality rate formerly associated with this procedure resulted from the disease process already present or the subsequent postoperative complications, rather than from the consequences of the actual vein ligation itself.

This paper was to have been presented at the meeting of the Society of University Surgeons, New York, N. Y., Feb. 8, 1945. (Meeting canceled.)

Successful ligation of a major venous trunk necessarily implies that an adequate alternative venous route is available. The necessary anastomoses about a point of obstruction in the inferior vena cava below the level of the renal veins must, in large measure, reflect the connections involved in its embryonic development. The systemic venous drainage in very young embryos is first represented by paired longitudinal channels known as the cardinal veins.⁴⁰ The anterior cardinal veins drain the blood toward the heart from the cephalic portion of the body. In the posterior cardinal veins the blood flows forward from the caudal portion of the body. At the level of the heart the anterior and posterior cardinals on each side of the body become confluent with each other as the common cardinal veins or ducts of Cuvier (Fig. 1, *A* and *B*). The common cardinal vein from each side of the body turns mesiad and enters the sinus venosus of the developing heart. Throughout their course the posterior cardinal veins receive lateral somatic and visceral branches in more or less perfect segmental succession.

In the early stages of development, the only portion of the definitive inferior vena cava which exists is the portion which intervenes between the liver and the sinus venosus. This portion is represented by the terminal part of the right omphalomesenteric vein. The more caudal portion of the inferior vena cava is contributed to by a number of different vessels. Among these is a pair of veins developing in the ventromedial portion of the mesonephroi which is utilized in the formation of the inferior vena cava at what will be the future renal level. These are the subcardinal veins (Fig. 1, *A* and *C*). As development progresses the two subcardinals become united with one another across the midline. This union constitutes the intersubcardinal anastomosis (Fig. 1, *B* and *D*). Cephalic to the anastomosis, the right subcardinal extends forward in the mesonephros, approaching in its course a fold of the dorsal mesentery known as the caval plica. Small venous channels in the caval plica form a connection with the right subcardinal, and coursing forward empty into the developing plexus of veins in the liver. Rapid enlargement of this new small vessel in the caval plica gives rise to what is commonly known as the mesenteric portion of the inferior vena cava. Excavation of the liver sinusoids to form a main channel through the liver substance gives rise to the hepatic portion of the vena cava.

Caudal to the intersubcardinal anastomosis the inferior vena cava is derived from the right supracardinal vein. The supracardinal veins appear late in development as paired channels draining the dorsal body wall. They soon acquire anastomotic connections with the sinus as did the postcardinals earlier. Cephalic to the sinus, parts of the supracardinals persist as the azygous vessels draining in a somewhat variable manner into the reduced proximal part of the right postcardinal (Fig. 1, *E* and *F*). Caudal to the anastomosis of the supracardinals with the subcardinal sinus, they gradually become the principal drainage channels of blood returning from the legs and pelvis. With the anastomosis of the right and left iliaes (old postcardinal tributaries), the blood returns increasingly by the right supracardinal which gradually enlarges to form the postrenal portion of the inferior vena cava. Vestiges of the left supracardinal vein are represented by longitudinal channels known in the adult as the ascending lumbar (Fig. 5), which become continuous with the azygous system superiorly and in this manner are associated directly with the superior vena caval system (Fig. 1, *E* and *F*). Likewise, small accessory supra-

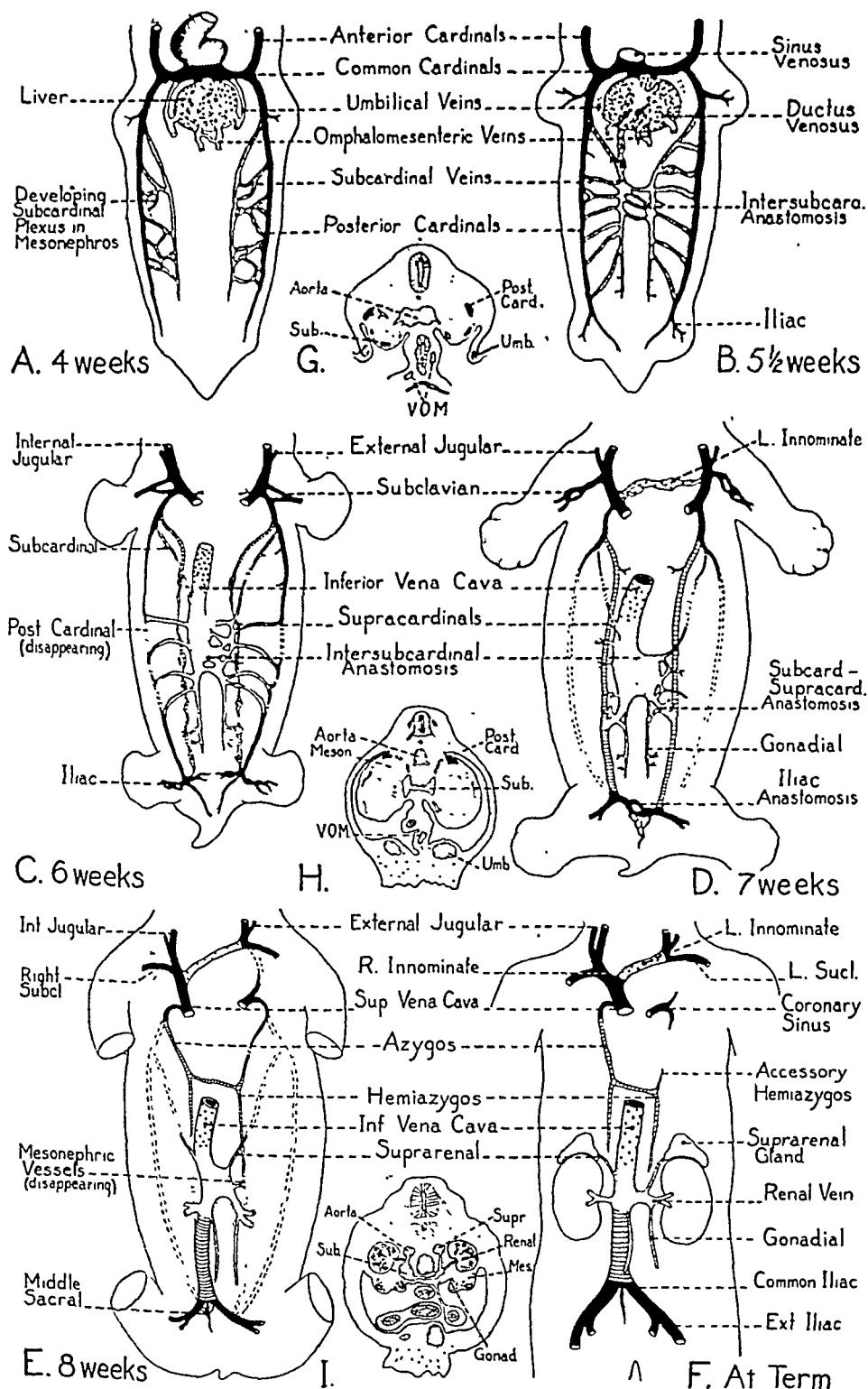


Fig. 1.—Schematic ventral views showing some of the steps in the development of the inferior vena cava. The cardinal and omphalomesenteric veins are shown in black, the subcardinal system is stippled, the supracardinals are horizontally hatched, and vessels arising independently of these three systems are indicated by small crosses. (Diagrams by Patten, based on the work of McClure and Butler, from Morris' Human Anatomy, Philadelphia, The Blakiston Company.)

cardinal channels on the right represent vestiges of the primitive condition when, as is the case with all developing main channels, the vessels in that location were plexiform.

This plexiform arrangement retains its embryonic configuration about the vertebral column in the form of the intra- and perivertebral plexus of veins (Fig. 6). These vessels lack the longitudinal arrangement of the more highly developed channels, possibly because during embryologic life the return flow of blood was cared for primarily by the developing inferior vena cava. These primitive vessels communicate with the inferior vena cava through segmental branches and play an important role in the passage of blood about a point of ligation of the inferior vena cava. They communicate with the ascending lumbar and azygous system and thereby maintain communications with the inferior and superior vena cava throughout the length of the spinal column.



Fig. 2—Roentgenogram of the injected veins of the pelvis of a cadaver following clamping of the inferior vena cava with hemostats at two levels below the entrance of the renals. The extensive filling of the pelvic and vertebral vessels, as well as the ascending lumbar and section of inferior vena cava between hemostats is well shown.

Although we have been aware of the fact that caval ligation in cases of acute ascending thrombophlebitis and phlebothrombosis involving the pelvic vessels is a life-saving measure, we have been reticent to employ this procedure because of the widespread importance placed upon the continuity of this largest vein of the body. With this in mind, one of us (R. O. N.) with an associate¹¹ attempted to determine the more important pathways by which blood is returned to the heart following ligation of the inferior vena cava below the renal vein. Unimballed cadavers were eviscerated and the aorta and its branches removed to facilitate work with the veins. The superior vena cava was ligated at its entrance into the heart and the inferior vena cava was

removed from the region of the renal vein superiorly. A No. 10 cannula was inserted into the femoral vein by way of the saphenous on one side and the system irrigated with warm saline to extricate as much clotted blood as possible. When a free flow of saline solution was obtained, the inferior vena cava was clamped just above the bifurcation and again in the region just below the renals. Warm saline solution was again allowed to flow through the system, this time in an attempt to cleanse the collateral system. A thin suspension of red lead was forced into the system under ten pounds of pressure for a period of one minute, following which the cannula was removed and the saphenous vein ligated. Roentgenograms were taken and the injected venous channels dissected.



Fig. 3—Roentgenogram of the thorax of an injected cadaver showing the extensive filling of the intercostal and vertebral vessels as well as the superior vena cava. The injection was by way of the femoral vein and followed ligation of the inferior vena cava below the renal level and excision of the inferior vena cava above the level of the renals.

In no case, during the period of lead injection, was there delay in filling of the inferior vena cava above the lower clamp (Fig. 2). The superior vena cava rapidly filled (Fig. 3), as might be anticipated, by way of the ascending lumbar and the segmentals which associate directly with the vertebral plexuses through the spinal veins and above the diaphragm by the azygous system which receives the segmental veins and terminates in the superior vena cava. Communications between the inferior vena cava and the vertebral systems are as follows: (1) Four segmental tributaries of the lateral sacral veins pass medially from the hypogastric veins to enter each of the anterior sacral foramina to communicate with the internal vertebral plexus (Fig. 4). (2) Two large ascending lumbar veins on each side pass from the common iliac veins upward along the lateral aspect of the vertebral bodies (Fig. 5). These anastomose with one another and become continuous superiorly with the azygous

system. At each segment these veins communicate with the external and internal vertebral plexuses by way of the segmental spinal veins passing through the intervertebral foramina, and with the anterior vertebral veins contributing to the external plexus. The external plexus also anastomoses with the basi-vertebrals through the vertebral bodies, which are themselves tributaries of the internal plexus (Fig. 6). An inconstant middle sacral vein passes from the common iliac downward over the sacrum, anastomoses with the lateral sacral veins, and passes directly into the vertebral plexus through the sacro-coccygeal foramina. (3) Laminectomy revealed the large internal vertebral plexus on the surface of the dura mater of the spinal cord (Fig. 6). It also showed the large venous sinuses running more or less longitudinally on each side, ventrolateral to the dura. These veins were all very well filled with the injected media. (4) The intra- and perivertebral plexuses communicate with the segmental veins which in turn drain into the vena cava.

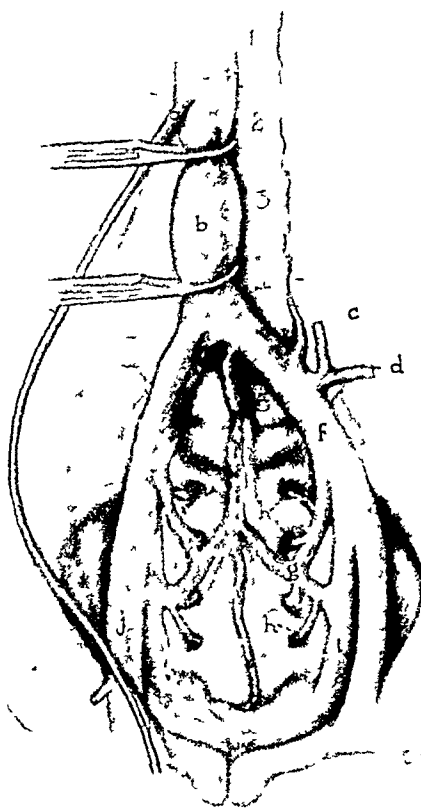


Fig. 4—Drawing made from an injected cadaver to show the plan of the veins of the pelvis. The vena cava has been ligated so all anastomotic vessels below the obstruction appear strongly dilated.

By means of these plexuses about the vertebral column, plus the free anastomoses about the point of obstruction, there was ready filling of the vena cava above the obstruction, of the azygos system, the intercostal veins, and the superior vena cava. Since all abdominal viscera were removed, communications with the portal system were not verified.

The inferior vena cava has been our site of election of vein ligation in ten patients. In three patients saphenous ligation had been done at an earlier date. In one patient a femoral vein ligation, above the level of the profunda

femoris branch, had been done, and in another patient ligation of the right ovarian vein was carried out at the time of caval ligation. The first patient of this group was operated upon twelve months ago. The most recent caval ligation was done within one month of this writing. In no patient of this group have anticoagulants been used in either the preoperative or postoperative period.

The patients here reported were seen during various stages of the disease. One patient was seen one day following the onset of leg edema, and the onset, signs, and symptoms were characteristic of the syndrome frequently spoken of as phlebothrombosis. None of the remainder of the patients was seen at the time of onset of the thrombotic process. In seven of the patients the character of onset as well as some of the immediate sequelae indicated a bland thrombosis of the deep venous system. In two patients the onset suggested a femoro-iliac thrombosis. One patient developed a deep suppurative thrombophlebitis following the injection of a sclerosing substance for the treatment of varicose veins. Chronic thrombosis had recurred in one patient over a

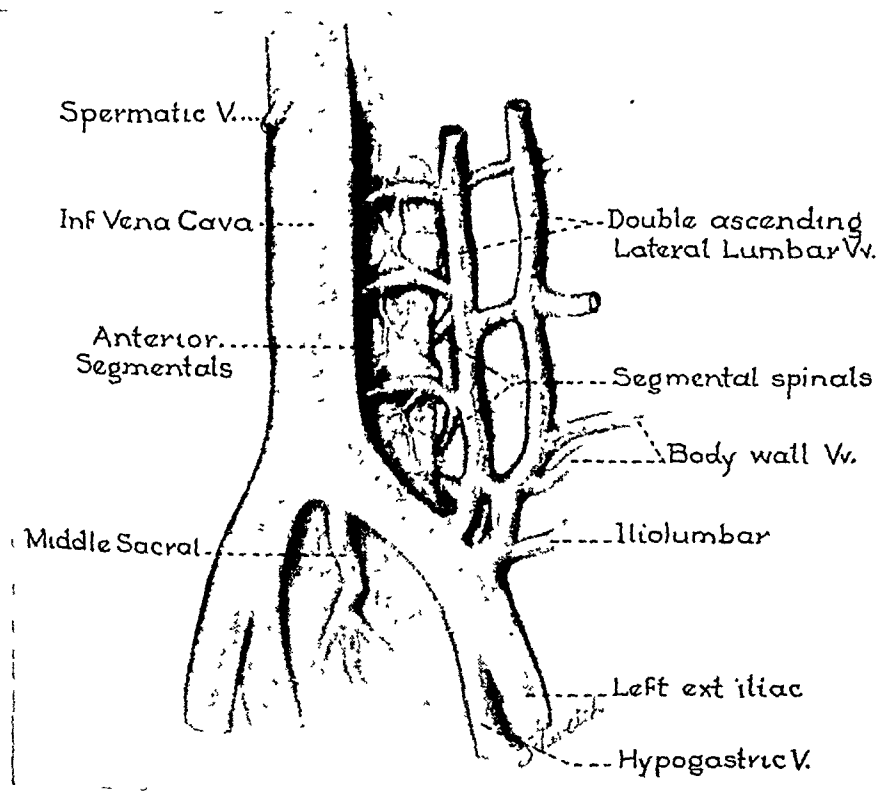


Fig. 5.—Drawing made from an injected cadaver showing the connections between the ascending lumbar veins and the vertebral plexus of veins.

period of ten years. In three patients there was a definite clinical history of one or more pulmonary infarcts; in three patients definite evidence of pulmonary infarction was present at the time of operation. One patient gave an atypical history of substernal oppression which had been diagnosed and treated as pylorospasm prior to the onset of the thrombosis. No roentgen evidence of pulmonary embolism was obtained. This last patient has been followed for a period of four months since caval ligation without recurrence of the abdominal symptoms. No thrombus was present within the cava at the time of operation, so that phlebotomy and thrombectomy were not indicated. In three patients

there was no history suggesting embolism with pulmonary infarction. Five of the ten patients had had chronic recurring ulcerations of the lower extremities prior to caval ligation. In one patient, whose symptoms had been present for a period of eight months, low back pain was a predominant symptom. In two other patients low back pain has been present for a variable period postoperatively. In three patients distention of the superficial lower abdominal veins has been remarkable. The patients in this series vary in ages from 27 to 74 years. Thus, of the ten patients, three presented themselves because of multiple, recent pulmonary emboli (one of these had also chronic recurring leg edema with ulceration), four because of chronic edema of the legs with ulceration, two because of painfully swollen legs without ulceration, and one because of epigastric pain associated with phlebothrombosis.

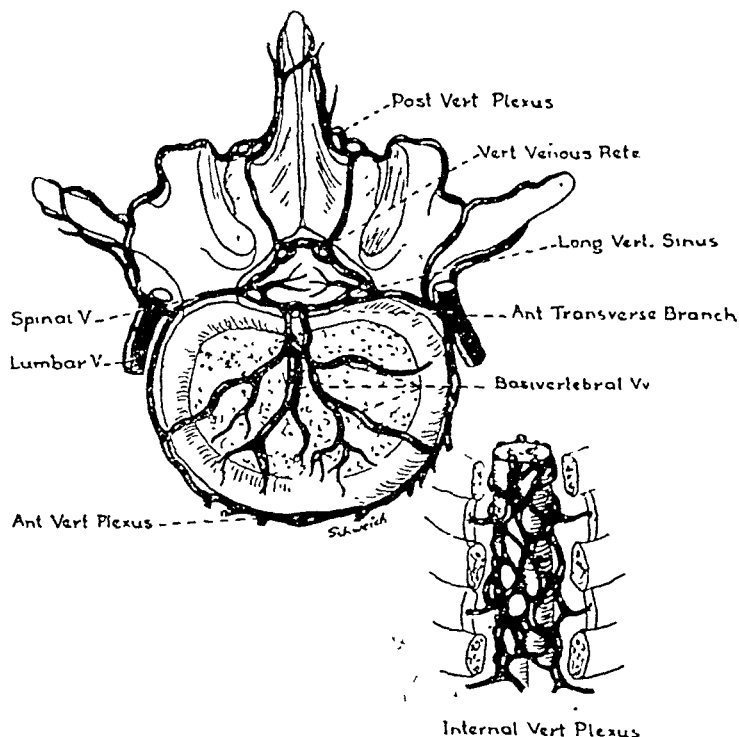


Fig. 6.—Diagrammatic sketch of the inter- and perivertebral plexus of veins. (From Morris Human Anatomy, 12d. 10, Philadelphia, 1942, the Blakiston Company.)

In each instance the inferior vena cava was exposed just above its bifurcation through a right transverse incision made at the level of the umbilicus and in each instance the entire exposure was retroperitoneal. In one patient, not considered in this series, an unsuccessful attempt was made to isolate the inferior vena cava but the structure could not be identified. There was considerable enlargement on the retroperitoneal lymph nodes with much perinodal reaction about these structures, and a subsequent diagnosis of lymphoblastoma was verified. Various types of ligature material have been used including No. 1 black silk, No. 1 chromicized catgut, and $\frac{1}{4}$ inch cotton umbilical tape. The latter material has been used with the greatest frequency. In only one instance was the vena cava transected following ligation. In the remainder of the cases, the vessel was ligated in continuity. Postoperatively, compression bandages were kept continuously about the lower extremities and the patients were encouraged to move about freely in bed. External supports were advised in all instances until no further edema was present in the legs after sustained activity.

In no patient did severe swelling occur in the immediate postoperative period. However, all patients had a varying degree of swelling immediately postoperatively and this increased to a variable degree after mobilization began.

We noted a mild flare-up of the thrombotic process in two patients during the course of their convalescence, and in a third patient this process was quite severe, involving not only the superficial but the deep venous channels. This latter patient had had a suppurative form of thrombophlebitis with a staphylococcus septicemia one year prior to caval ligation.

Ligation of the inferior vena cava is attended by a variable, but usually marked, increase in the venous pressure in the lower extremities. In two patients this necessitated numerous ligations of prominent varicose veins in the legs, and in another, ligation of the enlarged thoraco-epigastric veins. These ligations were not attended by increased swelling in the legs. The venous pressure has remained elevated to a varying degree in all patients to date. In the one patient upon whom ligation was carried out twelve months ago, the venous pressure in the legs is still twice that in the upper extremity although he is free of edema.

Since it is conceded that there is probably increased venous blood flow through the paravertebral venous plexus as a result of the numerous anastomoses conducting blood into this system, it was feared that varices might well occur in this system. There have been no clinical symptoms to suggest that varices have occurred in any patient. Measurement of the venous pressure in this system has not been undertaken. However, examination of spinal fluid pressures, and quantitative chemical analysis of the spinal fluid in patients have failed to give any indication of abnormalities which might result from an increased filtration pressure. All pressures were within the accepted normal range, and levels of total protein, chlorides, and sugar were also within normal limits. These studies were carried out on patients two weeks, five months, and twelve months following caval ligation.

The chronic supramalleolar ulcers which were present in five patients have shown a varied response to caval ligation. In one patient the ulceration healed during the immediate postoperative period and has remained healed for four months. In a second patient the ulcer healed, only to recur with the appearance of superficial surrounding varices. Healing occurred only after these were ligated and there has been no further recurrence in eight months. In a third patient similar healing and recurrence occurred. Following a period of bed rest for one week, complete healing resulted. The entire healed area has been recently excised and a graft applied. In the two remaining patients healing occurred in the immediate postoperative period but the time elapsed since operation has been too short to determine whether these ulcers will remain healed or whether further treatment will be necessary.

All patients are still wearing external supports, elastic knee-length hose or elastic bandages. By this means the edema of the legs is well controlled. In the one patient upon whom caval ligation was done twelve months ago, these have been removed intermittently for short periods, without recurrence of edema. The venous pressure in the legs of this patient is 270 mm. H_2O , twice that in the upper extremity, and some 70 mm. above the arbitrarily accepted level at which his edema might be expected to appear.

From our experiences to date an adequate collateral circulation, as evidenced by a normal venous pressure, may not be expected in those individuals with a long-standing thrombosis of the deep venous system of the lower ex-

tremities, in less than twelve months after ligation of the inferior vena cava. However, the clinical appearance of edema is easily prevented and controlled by the use of elastic external supports. The degree of immediate postoperative edema is minimal. This is in contrast to the sometimes severe and profound swelling which occurs occasionally after femoral vein ligation. We feel that the degree of immediate postoperative edema, and probably its duration, is greatly lessened as higher levels of venous ligation are carried out. The operative procedure has been well tolerated by these patients and no fatalities have occurred.

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OSTEOMYELITIS OF THE SKULL—ITS TREATMENT WITH PENICILLIN AND REPAIR OF THE DEFECT WITH TANTALUM

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OSTEOMYELITIS of the frontal bone, secondary to frontal sinusitis, is one of the most fatal of surgical diseases. Its treatment is often unsatisfactory because spread of the infection is difficult to control by the ordinary methods, particularly in the acute fulminating cases. The primary infection, acute sinusitis, is fairly common, but the complication of frontal osteomyelitis is relatively uncommon. Accurate statistics on the incidence of frontal osteomyelitis secondary to frontal sinusitis are not available. Certainly more cases occur than the number published in the literature. Yerger¹⁵ reported 125 cases collected from the literature up to 1931, but gave no estimate as to the percentage incidence. In a series of eighty-six cases of frontal sinusitis reviewed by Mac Millan,¹⁰ thirty-six (40 per cent) showed extension to frontal osteomyelitis, with a mortality of 14 per cent. This incidence of 40 per cent osteomyelitis is certainly much too high in an over-all review of frontal sinusitis. In cases of frontal osteomyelitis, Ballinger and Ballinger¹ gave an over-all mortality of 35 to 79 per cent and feels that it is much higher in the postoperative than in the spontaneous cases.

The anterior and posterior walls of the frontal sinus correspond to the outer and inner tables of the skull respectively, so that extension of infection within the sinus up into the diploic spaces of the frontal bones is an obvious possibility. The veins of the mucous membrane of the frontal sinuses are continuous with the diploic veins of the frontal skull. The diploic veins (Breschet veins) are nutrient vessels derived chiefly from the intracranial vessels through the inner table, so that the dura seems to attract the infection more strongly through the inner table than through the outer table periosteum.

In infections of the frontal sinus, the offending organism is usually the *Staphylococcus aureus* and occasionally hemolytic streptococcus or pneumococcus. If a thrombophlebitis supervenes in the sinus infection, the infection extends upward into the marrow between the tables of the skull where the circulation is of the closed (sinusoidal) type. The organisms extend by contiguity or in some instances by embolism, so that diffuse spreading or local islands of osteomyelitis occur. McCollum¹² states that the presence of bacteria leads to necrosis of surrounding tissue and the fact that this necrosis extends for a wider area than the clumps of bacteria means that they produce a toxic substance. These changes have been adequately described by Mosher¹³ and Furstenberg.⁵

It is well known that osteomyelitis is usually a slow disease, even in acute cases, and its manifestations depend on the virulence of the organism and resistance of the host. In discussing its phases, it is frequently divided into two types: (1) acute (fulminating) and (2) chronic (less virulent forms).¹⁴ Brunner³ subdivides the acute into (a) fulminating and (b) protracted types; and the chronic into (a) primary and (b) secondary forms. This classification, although having some clinical support, is too cumbersome for average use and is admittedly considered indefinite. Williams and Nichols¹⁷ conveniently divide frontal osteomyelitis into three types: (1) fulminating; (2) localized, self-limiting type that heals spontaneously; and (3) the slowly spreading type that forms Pott's puffy tumor (pericranial abscess). From a review of the literature it appears that the acute form can be designated as that in which the osteomyelitic process is spreading and has associated systemic reaction of varying degree. The chronic form can be designated as the localized "burned out" type with repeated sequestrum formation and little or no systemic reaction. The three cases to be presented here can be called acute osteomyelitis, spreading, but not fulminating type. The fulminating form most commonly follows swimming, has a very rapid course, and carries a high mortality due to intracranial extension.

The diagnosis is made early by evidence of pain and extending pitting edema of the scalp, and by x-ray changes manifested by a "smudge" that is due to the loss of the discrete mucoperiosteal outline of the frontal sinus. Ten days to two weeks later, when the area of demineralization has assumed the characteristic "moth-eaten" appearance, the diagnosis is no longer in doubt.

The form of treatment varies with the exigency of the case at hand. In the fulminating type with the patient critically ill, and manifested by pitting doughy edema of the forehead, it is imperative to do wide

radical removal of the diseased osteomyelitic bone. Fred⁴ advocated the use of sulfonamide drugs in addition to operation and states, "I am convinced that chemotherapy will surely modify, even revolutionize the treatment of osteomyelitis—but incision and drainage must be instituted as well." The dependency on sulfonamide drugs is challenged by Jones,⁷ who feels that these drugs have their limitations in the treatment of such conditions. The bacteriostatic properties of sulfonamide therapy in staphylococcus infections are inhibited by increased synthesis of para-amino benzoic acid at the site of infection. Our experience shows that penicillin has definitely revolutionized the treatment of osteomyelitis of the skull of sinus origin in that it is an excellent bacteriostatic agent, overcomes the infection rapidly, and limits its spread, thus permitting early operation with primary closure of the wound and rapid recovery. Until recently, the classical inverted T incision was used with open packing of the wound and subsequent deforming scar of the forehead.^{2, 14} With the use of penicillin, a coronal incision is preferable, giving a more adequate exposure and allowing the removal of the diseased bone in one piece, so avoiding a deforming scar of the frontal scalp. When healing is complete and all evidence of infection has disappeared, cosmetic repair of the underlying bone defect with insertion of a tantalum plate is carried out easily. The restoration of the smooth contour of the forehead is easily accomplished.

CASE REPORTS

The following three cases to be reported involved young adults in Military Service and will be given in the sequence of hospital admission. It so happens that the first patient was the most critically ill and the second and third less ill, consecutively.

CASE 1.—G. M., aged 27 years, was admitted to Bushnell General Hospital, July 4, 1943. This aviation cadet gave a history of chronic sinusitis for several years and was treated by having a submucous resection in 1938 and removal of nasal polyp October, 1942. He was in good health until his present illness except for occasional nasal obstruction and postnasal discharge. On routine physical examination, March 27, 1943, he was found to have a right pansinusitis and so was admitted to a Station Hospital for its correction. Treatment consisted of daily nasal irrigations for ten days and as there was no improvement, a right intranasal antrostomy was done April 5, 1943. His condition remained good for the first seven days postoperatively, but on April 12, 1943, he developed a slight fever, some swelling of the right side of the face and eyelid, and pain. He was treated with hot compresses, and started on sulfadiazine, 6 Gm. daily. His temperature elevation subsided for three days and then began a steady progressive daily elevation, reaching 103° F. and an extension of a fluctuant swelling into the right canine fossa. April 21, 1943, this was incised. The infection continued to spread so that between April 21 and June 4, 1943, he had seven operations carried out in the right antrum, ethmoids, both frontal sinuses, and the forehead scalp, but without improvement. By May 24, 1943, he had developed pitting edema of the left side of the forehead and on May 26, 1943, the first signs of osteomyelitis of the frontal bone were evident by x-ray. During his entire three months' treatment at a Station Hospital he had received 442 Gm. of sulfadiazine with a sustained blood level of 7.1 to 13.6 mg. per cent but without apparent benefit. He had also received 3,200 c.c. of whole blood in nine transfusions. The culture of all the abscesses showed nonhemolytic staphylococcus.

He was transferred to Bushnell General Hospital July 4, 1943, because of the spreading frontal osteomyelitis. Examination on admission showed a chronically ill, undernourished patient with multiple draining sinuses of the right side of the

face and forehead, all exuding frank pus. He was clear mentally and cooperated well. The systemic review was negative. Complete neurologic examination was normal except for complete anosmia, proptosis and chemosis of the right eye, and a diplopia in all directions. There was anesthesia of the first and second divisions of the fifth nerve on the right side and a right facial weakness of peripheral type. The remainder of the examination was negative. Lumbar puncture showed a pressure of 150 mm. of water and the fluid contained five cells, total protein 50 mg., and the smears and cultures showed no organisms. Blood studies showed red blood count, 4,190,000, with hemoglobin, 82 per cent; white blood cells, 14,800; polymorphonuclears, 75 per cent; lymphocytes, 21 per cent and eosinophiles, 4 per cent; hematocrit, 40 per cent; sedimentation rate, 53 mm. per hour; plasma protein 7.3; blood chlorides, 585. Cultures of the draining sinuses of the face and forehead showed hemolytic *Staphylococcus aureus*, coagulase positive. The diagnosis on admission was osteomyelitis, acute, severe, right maxilla, ethmoid and frontal bones, secondary to chronic pansinusitis. There was no neurologic evidence of intracranial extension. (Figs. 1 and 2.)

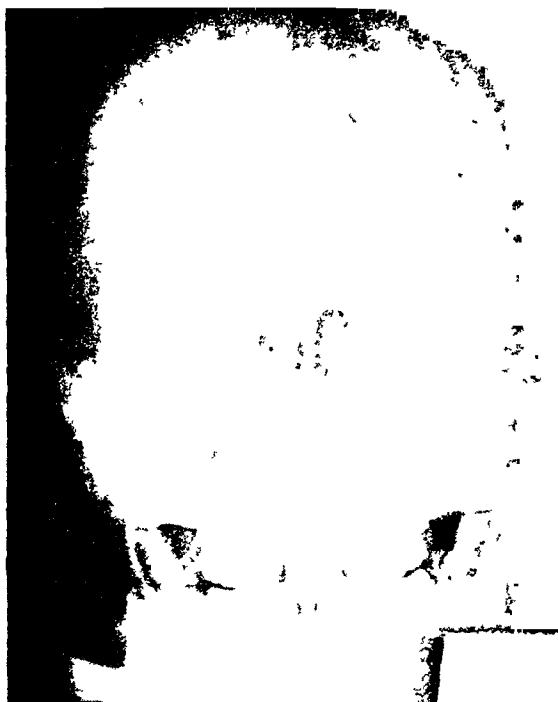


Fig. 1.—G. M., Case 1. Admission photograph, taken July 5, 1943, showing multiple draining wounds prior to administration of penicillin.

Course in Hospital.—Immediately after basic laboratory studies had been carried out, the patient was started on penicillin, being given 240,000 units intravenously daily for five days, July 5, 1943, to July 10, 1943, a total of 1,200,000 units.* Penicillin was also instilled locally into the draining sinuses (250 units per cubic centimeter). From July 10 to July 30, 1943, he was continued on 120,000 units intravenously, daily, receiving a total of 2,400,000 units during the twenty days. By July 24, 1943, all purulent discharge had stopped, temperature was normal, and he was much improved. It was thought the infection had been eradicated, but on Aug. 16, 1943, a purulent collection appeared in the forehead on the left side and was drained through a previous incision. Penicillin was again administered for another twelve days (total 2,040,000 units). The infection cleared again only to reappear in the forehead on the right side Sept. 6, 1943. It became evident that penicillin could readily control the infection but not overcome it, and some more radical measures were necessary. Penicillin was administered for the third course, a total of 360,000 units over three days. During the entire interval of treatment with penicillin, the patient received a total of 6 million units from July 5, 1943, to Sept. 10, 1943.

*The dosage used was that originally instituted by Lyons.²

Sept. 10, 1943, the first stage operation for frontal osteomyelitis was carried out. Through a coronal incision a transverse channel 1 cm. wide was removed along the coronal suture line behind the edge of diseased bone, and the external periosteum folded under healthy bone edge, as described by Schilling,¹⁵ and recently Van Wagenen.¹⁶ Penicillin was instilled locally to the forehead until



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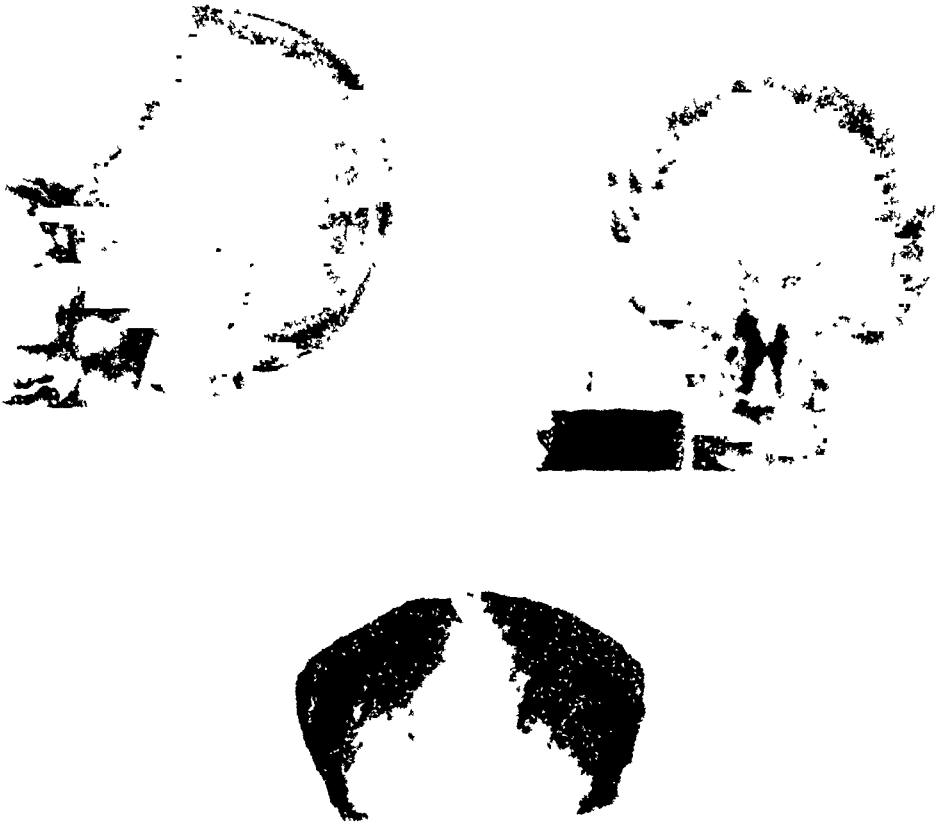


Fig. 3.—G. M. Postoperative X-ray pictures, anteroposterior and lateral, showing frontal skull defect and the excised bone fragment. (Nov. 18, 1943.)



Fig. 4, A and B.—G. M. Photographs taken two weeks postoperatively, Oct. 25, 1943, showing the coronal incision, slight depression of the forehead area, and healing of all the former forehead sinuses.

Sept. 17, 1943, when through the same coronal incision the entire skull anterior to the coronal suture was removed in one piece. There was one small area of granulation tissue on the dura, but no frank pus and no perforations were noted. A complete radical frontal operation was also carried out, preserving the supraorbital ridges. The wound healed per primum in five days, during which time he was given sulfadiazine, since he had become penicillin-resistant at the time of operation.¹⁹ (Figs. 3 and 4.)

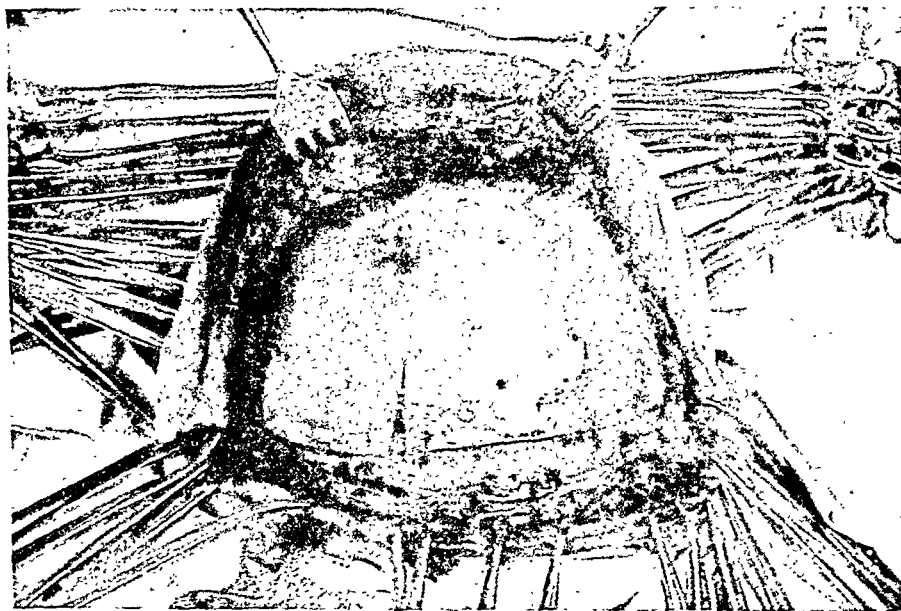


Fig. 5.—G. M. The tantalum plate anchored in position by means of tantalum wire (May 1, 1944). Note perforations referred to in text.

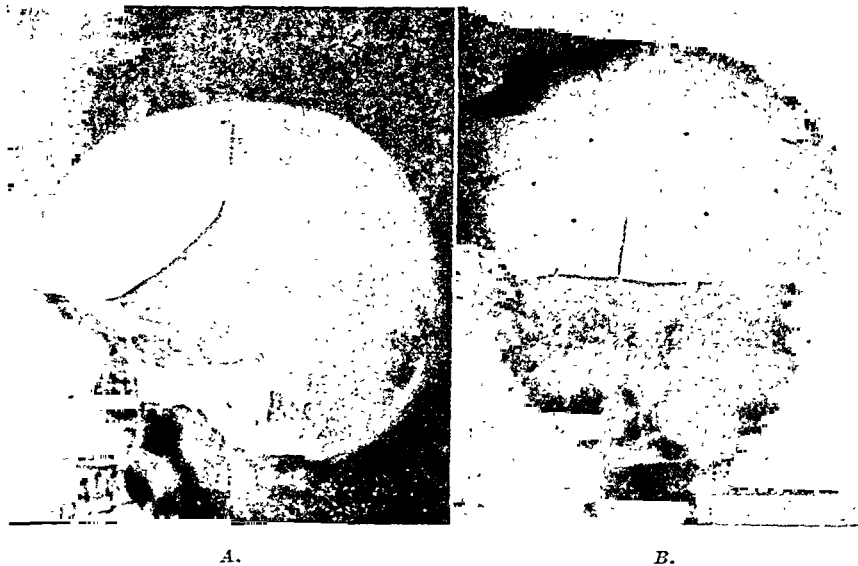


Fig. 6. A and B.—G. M. Postoperative x-ray anteroposterior and lateral views, May 17, 1944, showing tantalum plate firmly fixed in position.

He made a rapid recovery and became a librarian in the hospital. However, because of the large frontal defect, he desired a protective covering for the forehead, and so after making a plastic mold of the defect, a large tantalum plate was formed that weighed 105 Gm. and was 250 sq. cm. in size. (See technique under Discussion.) On May 1, 1944, the entire frontal scalp was turned down easily off the underlying dura through the former incision and the tantalum plate

solidly wired into place. The cosmetic result was considered excellent by the patient. He has been returned to limited duty and plans to have plastic operations about the old drainage scars done at a later date. (Figs. 5, 6, and 7.)

Comment.—This patient harbored a spreading frontal osteomyelitis for at least six weeks while under sulfonamide drug medication, without any improvement. After receiving systemic and local penicillin, improvement was dramatic after the first week, only to be followed by a relapse shortly after penicillin was discontinued. This occurred a second time, indicating that penicillin is an excellent bacteriostatic and not a bacteriocidal agent. It also shows that surgical removal of the diseased bone is usually necessary to effect a cure.



FIG. 7. A and B.—G. M. Anteroposterior and lateral photographs taken May 2, 1944, after insertion of tantalum plate to show restoration contour of frontal skull, facial scars to be corrected by plastic procedure.

CASE 2.—K. S. D., aged 37 years, was admitted to Bushnell General Hospital, Jan. 10, 1944. This soldier's past history was negative except for an auto accident in 1935, in which he sustained lacerations on the right side of the forehead, and epigastric distress since 1941.

He entered the service in September, 1943. One month later, Oct. 19, 1943, he entered a station hospital, complaining of epigastric pain of about two years' duration. A gastrointestinal x-ray made Oct. 23, 1943, showed the presence of a duodenal ulcer. At the same time he developed a severe nasopharyngitis that rapidly progressed into a pansinusitis. Treatment consisted of hot compresses, nasal shrinkage, and sulfanilamide, 1 Gm. four times a day. Oct. 30, 1943, he demonstrated furuncles of the nose with cellulitis, and an impending cavernous sinus thrombosis was suspected. At the same time he showed suppuration of the ethmoid and left maxillary sinuses. Sinus irrigations were carried out intermittently until Dec. 8, 1943, when a left frontal sinusotomy was done, but culture of the pus showed no growth. Blood count showed red blood cells, 4,870,000, with hemoglobin, 95 per cent. White blood count was 11,550; polymorphonuclears, 75 per cent; and lymphocytes, 25 per cent. Dec. 14, 1943, a similar operation was carried out in the right frontal sinus with good evacuation of pus. By December 8 he developed tenderness and swelling along the midline of the lower forehead that progressed to a right frontal abscess (Pott's puffy tumor) and was drained Dec. 12, 1943. The frontal abscess was drained again December 28 and at that time x rays showed the

typical moth-eaten appearance of osteomyelitis. Because of his continued downhill course he was transferred to Bushnell General Hospital for penicillin Jan. 10, 1944. He had received 272 Gm. of sulfonamide drugs during this time.



Fig. 8.—K. D. Case 2. Admission photograph, Jan. 11, 1944, showing draining frontal sinus prior to penicillin therapy.

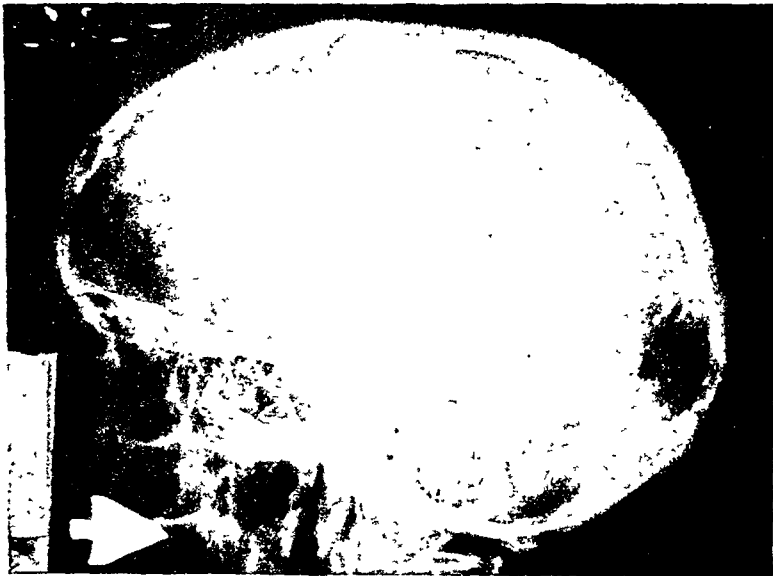


Fig. 9.—K.D. Lateral view of skull, preoperative, showing area involved by osteomyelitis. (Jan. 20, 1944.)

Examination on admission showed a thin, emaciated middle-aged man acutely ill and complaining of severe frontal headaches. There was a linear incision over the right supraorbital ridge draining frank pus. There was also tenderness in the low mid-frontal region, but no edema or induration. A detailed neurologic examination was entirely normal except for an early proptosis of the right upper eyelid. No evidence of intracranial extension was demonstrated.

Laboratory studies showed red blood cells, 3,230,000; hemoglobin, 63 per cent; white blood cells, 9,900; polymorphonuclears, 64 per cent; lymphocytes, 36 per cent;

plasma protein, 7.2 Gm. per cent. X-ray views showed extensive inflammatory thickening of the lining membranes of all air cells. There was extensive osteomyelitis of the frontal bones on both sides of the midline, but more extensive on the right. We feel the amount of destruction has increased, especially in the direction of the vertex and involves both the inner and outer table. Culture of the draining sinus showed aerobic nonhemolytic streptococci and nonhemolytic *Staphylococcus albus*.

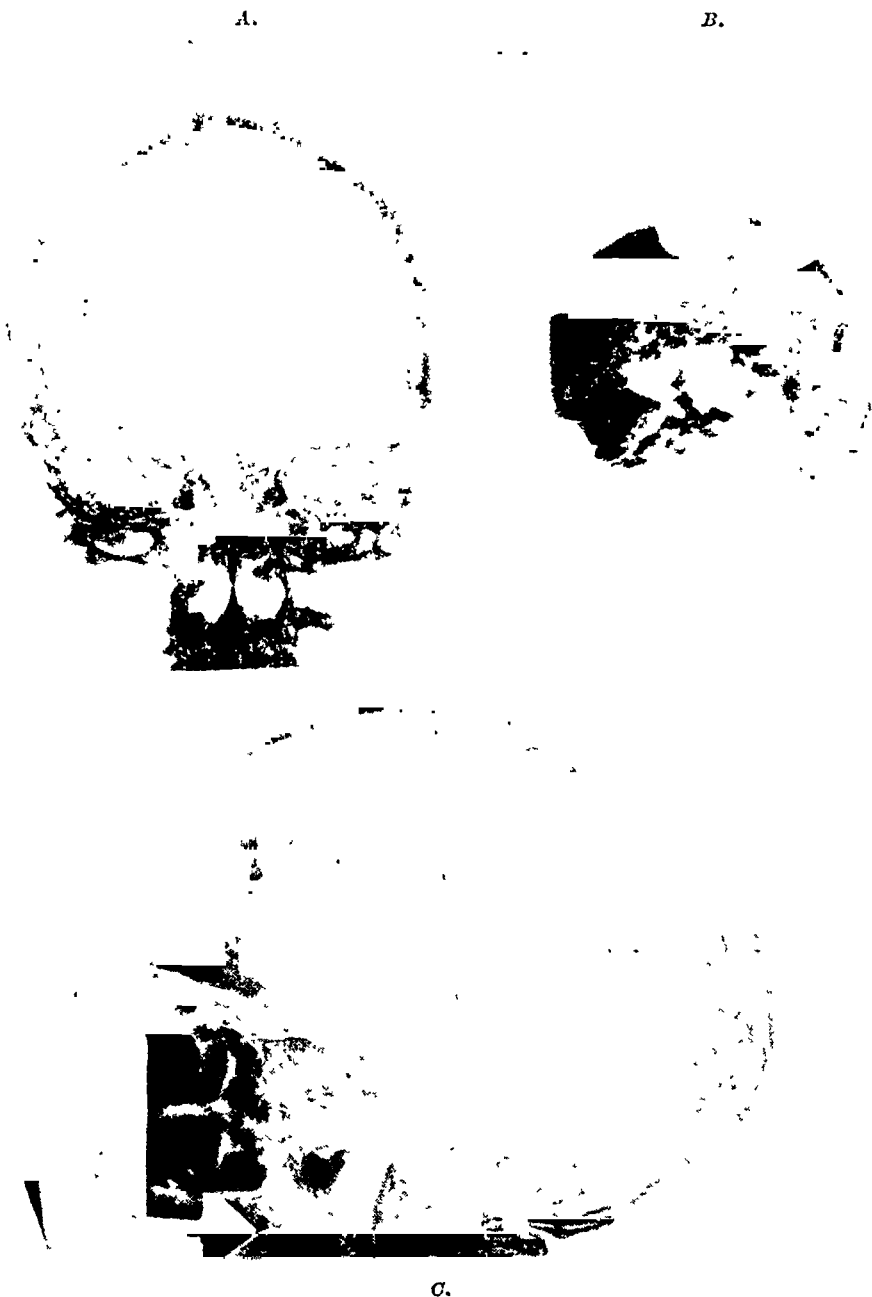


Fig. 10.—K.D. Anteroposterior (Dec. 7, 1944) and lateral (Jan. 31, 1944) post-operative views showing skull defect after removal of osteomyelitic area. Also photograph showing the involved bone removed (Jan. 22, 1944).

Diagnosis on admission was acute, nonfulminating, osteomyelitis of frontal bone, secondary to chronic pansinusitis. (Figs. 8 and 9.)

Course in Hospital.—Following determination of basic laboratory studies he was started on penicillin intramuscularly, receiving 200,000 units per day as well as local penicillin to the draining sinus. An ulcer diet was given in addition to ferrous sulfate. By Jan. 20, 1944, the drainage from the sinus incision had

stopped and the patient's condition was considered good for surgery. He had received a total of 2,000,000 units of penicillin with excellent bacteriostasis.

Jan. 22, 1944, through a coronal incision, the entire osteomyelitic area in the frontal bone was removed in one piece, and in addition, the medial half of the



Fig. 11. *A* and *B*—K.D. Post-operative anteroposterior (Feb 26, 1944) and lateral (Feb 2, 1944) photographs showing depression of forehead due to loss of bone



Fig 12—K.D. Tantalum plate (June 16, 1944) wired in place with tantalum wires. (The rakes are elevating the forehead scalp above the eyes)

right supraorbital ridge. There was no evidence of extradural granulation tissue or pus. The frontal sinuses were also exenterated. The wound was closed with out packing, but a small catheter was inserted through a stab wound for the purpose of continuing local instillations of penicillin. This was continued for four days only because the serous drainage was sterile. The incision healed per primum and he made an uneventful recovery. (Figs. 10 and 11.)

The postoperative defect was very evident and so he requested a plastic repair. A tantalum plate was prepared from a mold of the defect and on June 16, 1944, the plate was wired over the defect with a good restoration of the forehead contour. (Figs. 12, 13 and 14.)

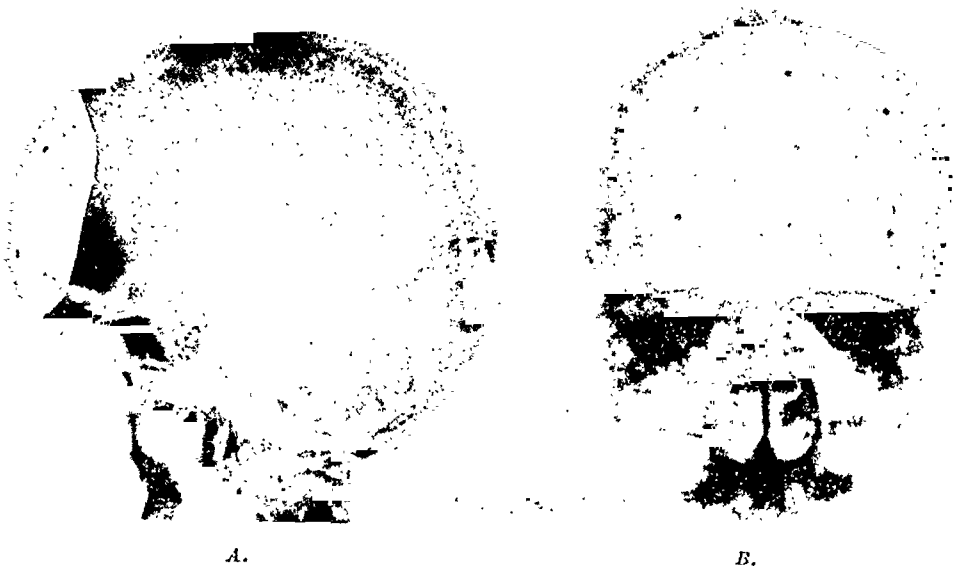


Fig. 13, A and B.—Anteroposterior and lateral x-ray views showing the tantalum plate in place (June 27, 1944).

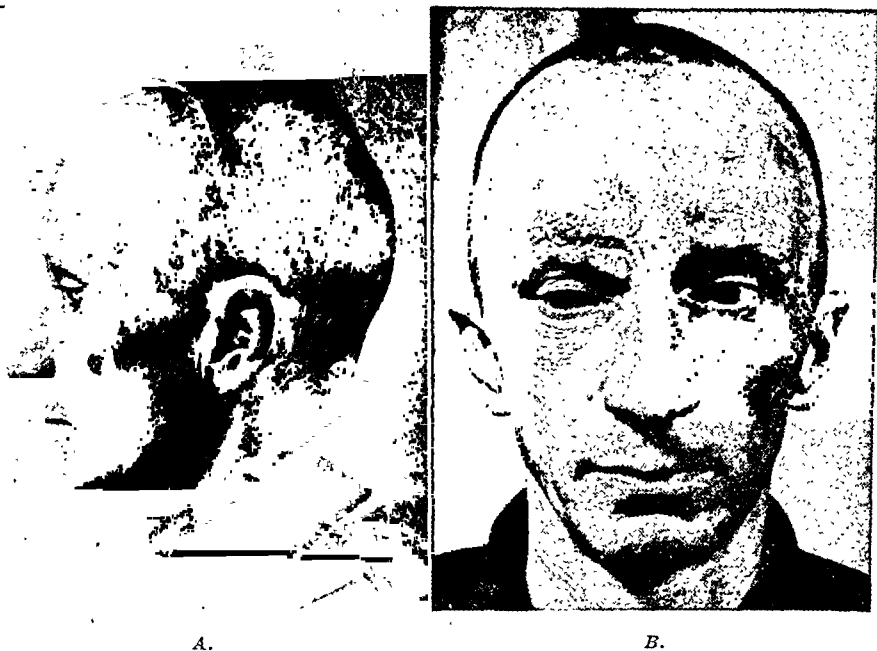


Fig. 14, A and B.—K.D. Final anteroposterior and lateral photographs showing restoration of contour of forehead and healing of all wounds, June 29, 1944.

This soldier is now feeling very well and would like to return to full duty. However, he will have to be discharged from the service because of a duodenal ulcer.

CASE 3.—E. C. M., aged 20 years, was admitted to Bushnell General Hospital March 25, 1944. This soldier had a negative history until the present illness.

On March 1, 1944, he developed an upper respiratory infection that he considered just an ordinary cold. However, on March 6, 1944, he experienced sudden severe pain over the left eye, accompanied by chills. On admission to a station hospital, March 8, 1944, examination proved negative except for tenderness on pressure over the left sinus region and redness and swelling of the left upper eyelid. The diagnosis of acute left frontal sinusitis was made and he was treated with nasal shrinkage, ice packs, sedatives, and sulfadiazine, having received 36 Gm. of the sulfonamide drug in six days without improvement. The white cell count was 15,100 with 91 per cent polymorphonuclears and on March 10, 1944, x-ray pictures of the sinus showed a bilateral pansinusitis with a fluid level evident in the left frontal sinus. By March 23, 1944, he developed severe left frontal headaches, early bilateral papilledema, left facial weakness, and a partial ptosis of the left eyelid. There was no evidence of edema of the frontal scalp on the left side. He was transferred to Bushnell General Hospital, on March 25, 1944, for treatment of a suspected left frontal lobe brain abscess.



Fig. 15.—E.M. (Case 3) Anteroposterior preoperative x-ray picture of skull showing involved area of osteomyelitis in left frontal region.

Examination March 26, 1944, showed the patient moderately drowsy and acutely ill. Temperature was 102.2° F., pulse 84, and respirations, 24. Complete neurologic examination was entirely negative except for the early ptosis of the left eyelid, mild left facial weakness, bilateral papilledema of two diopters, and generalized hyporeflexia. The only evidence of possible intracranial extension was the papilledema. Lumbar puncture showed an initial pressure of 360 mm. water. Twenty-five cubic centimeters of clear colorless fluid were removed until the final pressure was 140. The fluid contained 1 cell per cubic millimeter, total protein 30 mg. per cent, sugar 117, and cultures were negative. Roentgenograms taken April 3, 1944, showed extensive osteomyelitis of the left frontal bone, extending back to the coronal suture. There was diffuse clouding in the left frontal sinus, both ethmoids, and bilateral antral involvement. Laboratory studies showed red blood cells, 3,860,000; hemoglobin, 86 per cent, white blood cells 17,600; polymorphonuclears, 73 per cent; lymphocytes, 27 per cent; plasma protein, 6.8 Gm. per cent. Blood cultures were negative.

Diagnosis was chronic suppurative left frontal sinusitis and acute osteomyelitis of the left frontal bone. (Fig. 15.)

Course in Hospital.—Following completion of basic studies, March 30, 1944, he was started on systemic penicillin, 200,000 units daily intramuscularly for thirteen days. April 4, 1944, after he received 1,200,000 units of penicillin, a radical left external frontal sinusotomy was done. In addition, a needling of the left frontal lobe of the brain was done with negative findings. Cultures made of the sinus membrane and pus were sterile. The wound was irrigated with local penicillin for

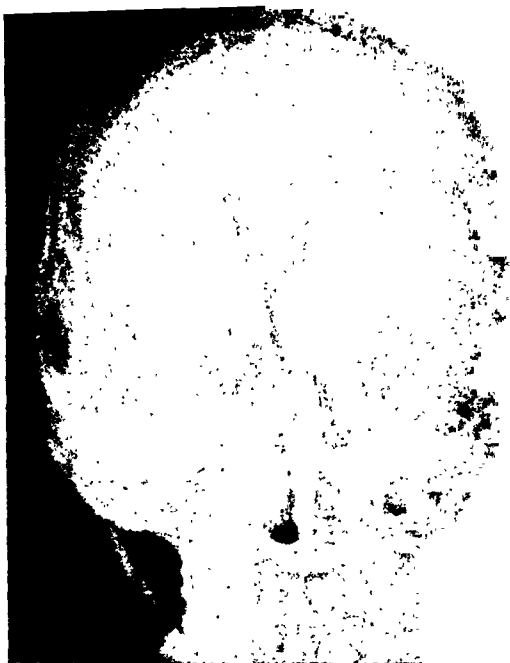


Fig. 16.



Fig. 17.

Figs. 16 and 17.—E.M. Fig. 16 is a ventriculogram, April, 1944, showing shift of ventricles. Fig. 17 is a final ventriculogram, July 8, 1944, showing the postoperative defects of left frontal sinus with osteomyelitis all healed.

On March 1, 1944, he developed an upper respiratory infection that he considered just an ordinary cold. However, on March 6, 1944, he experienced sudden severe pain over the left eye, accompanied by chills. On admission to a station hospital, March 8, 1944, examination proved negative except for tenderness on pressure over the left sinus region and redness and swelling of the left upper eyelid. The diagnosis of acute left frontal sinusitis was made and he was treated with nasal shrinkage, ice packs, sedatives, and sulfadiazine, having received 36 Gm. of the sulfonamide drug in six days without improvement. The white cell count was 15,100 with 91 per cent polymorphonuclears and on March 10, 1944, x-ray pictures of the sinus showed a bilateral pansinusitis with a fluid level evident in the left frontal sinus. By March 23, 1944, he developed severe left frontal headaches, early bilateral papilledema, left facial weakness, and a partial ptosis of the left eyelid. There was no evidence of edema of the frontal scalp on the left side. He was transferred to Bushnell General Hospital, on March 25, 1944, for treatment of a suspected left frontal lobe brain abscess.

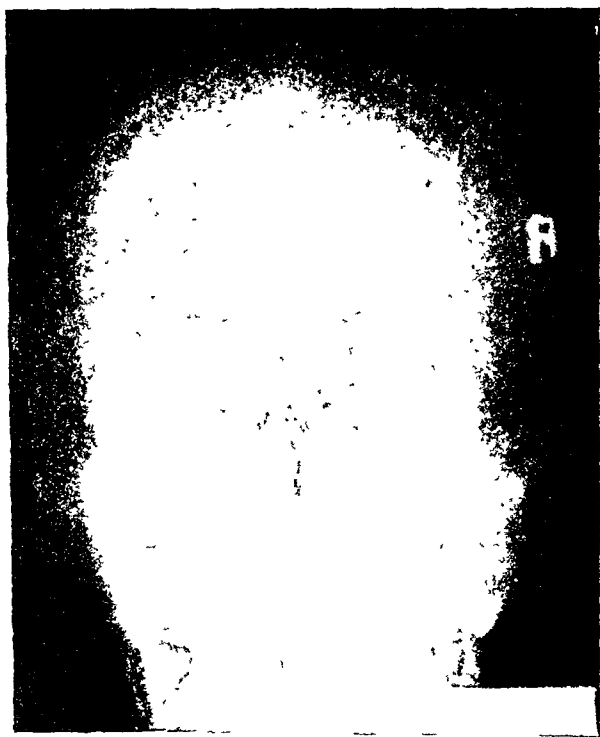


Fig. 15.—E.M. (Case 3) Anteroposterior preoperative x-ray picture of skull showing involved area of osteomyelitis in left frontal region.

Examination March 26, 1944, showed the patient moderately drowsy and acutely ill. Temperature was 102.2° F., pulse 84, and respirations, 24. Complete neurologic examination was entirely negative except for the early ptosis of the left eyelid, mild left facial weakness, bilateral papilledema of two diopters, and generalized hyporeflexia. The only evidence of possible intracranial extension was the papilledema. Lumbar puncture showed an initial pressure of 360 mm. water. Twenty-five cubic centimeters of clear colorless fluid were removed until the final pressure was 140. The fluid contained 1 cell per cubic millimeter, total protein 30 mg. per cent, sugar 117, and cultures were negative. Roentgenograms taken April 3, 1944, showed extensive osteomyelitis of the left frontal bone, extending back to the coronal suture. There was diffuse clouding in the left frontal sinus, both ethmoids, and bilateral antral involvement. Laboratory studies showed red blood cells, 3,860,000; hemoglobin, 86 per cent, white blood cells 17,600; polymorphonuclears, 73 per cent; lymphocytes, 27 per cent; plasma protein, 6.8 Gm. per cent. Blood cultures were negative.

Diagnosis was chronic suppurative left frontal sinusitis and acute osteomyelitis of the left frontal bone. (Fig. 15.)

sterile in all the cases, permitting primary closure of the wound in each instance. Following the use of penicillin in cases requiring surgery, we feel that use of a coronal incision with the turning down of the entire forehead and removal of the osteomyelitic area in one piece and then primary closure is definitely preferable to the formerly used inverted T incision, open packing of the wound, and the resulting deforming scar.^{2, 14}

The correction of a defect in the skull depends upon the size of the deformity, its location, and the patient's concern about a "soft spot" on his head. Since the deformity of the forehead, not covered by hair, is most conspicuous, the patient is usually eager to have it corrected. We have used tantalum plate for covering the defect and find it very satisfactory. In view of the efficacy of penicillin in controlling infection, the question arises whether a plate should be prepared prior to the primary operation and be inserted at the time of removal of the osteomyelitic area, attempting to avoid a secondary operation. We think this should not be done for three reasons: first, the measurements and conformity of the plate would be indefinite as the actual defect can be determined at operation only; second, closure of the nasofrontal duct by healing granulation tissue is necessary after the primary operation to prevent recurring infection into the defect; third, large sheets of tantalum act as foreign bodies promoting infection in an already infected field even with the concomitant use of penicillin. Therefore, we advocate waiting at least three months following the primary operation and complete healing of the wound before completing the secondary plastic repair.

PREPARATION AND INSERTION OF THE TANTALUM PLATE FOR DEFECTS OF THE SKULL

Tantalum is the seventy-third element in the series 5 periodic table with a density of 16.6 and virtually no electrogalvanic action. It is very resistant to corrosion and chemical attack and has the necessary properties of malleability and ductility to lend it to a simple technique of fabrication. The .015 inch sheet tantalum is ideal for forming plates to correct the defects of the skull. Per square area, the prepared plate is but slightly heavier in weight than the bone which it replaces, weighing 1.52 Gm. per square centimeter.

The preparation and insertion of the tantalum plate offers a wide range of choice to the surgeon. The preferred method is usually the one-stage operation which requires the fabrication of the plate previous to operation, by the indirect technique. The two-stage procedure necessitates the preparation of the bone ledge around the defect, and a direct impression of the mortise joint and the surrounding bone with later insertion of the plate after fabrication. The technique for swaging the plate is the same in either case.

The preferred impression material to be used in either method is the hydrocolloid type because of its accurate reproduction of detail of the defect and the surrounding skull or scalp contour. It lends itself to use over the scalp or bone equally well and may be sterilized in the autoclave and cooled to 98.6° F. for use. Dental impression compound or the algenate impression material may be used for smaller defects but is not as readily sterilized or as readily manipulated as hydrocolloid.

To prepare the hydrocolloid impression material, we use the following formula:

Agar	62 Gm.
Green soap	5 Gm.
Magnesium sulfate	3 Gm.
Cellulose fibers from 2 sanitary napkins	
Water	1,500 c.c.

The mixture is heated in a double boiler until it is of a smooth consistency, and cooled to 120° F. for impressions over the scalp. (It may be autoclaved and cooled to 98.6° F. for impressions of the bone in direct impression, using sterile technique.)

In the indirect method, which has been used in the cases discussed, an accurate impression of the scalp and orbital ridges is made after the margins of the defect are outlined by palpating the bone edge and marking it with an indelible pencil. The area to be reproduced by the impression depends on the size and location of the defect. Ordinarily, in areas where bilateral symmetry is important, or in the reproduction of the orbital ridge, a large impression, taking in the surrounding contour and the opposite side, is helpful in establishing the corrected contour of the defect in wax.

To facilitate removal of the impression and to limit the flow of material on application, a cardboard base (matrix) is made by cutting a hole in a suitable piece of heavy cardboard so that it fits on the skull around the defect like the brim of a hat without the crown. With the cardboard matrix in place, the impression material is painted over the defect and surrounding contour with a brush to a thickness of about one inch, care being exercised to prevent any air being trapped between the defect and the material. The hydrocolloid is then chilled for fifteen minutes by covering with towels soaked in ice water, and is then reinforced by a layer of plaster of Paris.

When the impression is "set" it is removed with the cardboard, the outline of the defect is traced with a knife blade over the marked outline, and the impression is then poured in dental stone. This reproduces the area in a master model that is an exact replica of the original defect, the edges of the defect presenting a beaded line. (Fig. 18.)

The defect in the stone model is then filled with dental wax and contoured with a heated spatula to correspond to the desired contour of the normal scalp. In all defects it is advisable to overcorrect the contour slightly, since the scalp becomes flattened over the defect and the plate is slightly depressed in its bed of bone. This corrected model is next reproduced in dental stone, Hydrocal, or Hydromite,* with the margins extending well beyond the desired edges of the tantalum plate to be made. A die and counterdie are then prepared of the selected stone by investing the die in the bottom half of a metal flask. Dental prosthetic flasks may be used for small plates, and flasks may be made of six-inch pipe for larger ones by welding in covers and guides for closing. It is important that a "lock edge" be prepared beyond the defect margin by preparing a somewhat abrupt downward contour or beaded line of the stone surface in order to "lock" the edges of the

*U. S. Gypsum,

tantalum plate while the stretching of the middle body of the plate is being accomplished. This, in short, gives an actual elevation of an area outside of the defect on the die. When the models have been well flaked, the tantalum plate (.015 inch thick), cut to approximate contour, but $1\frac{1}{2}$ inches oversize, is placed properly and the two halves of the flask are closed gradually within a cylinder, pressure being applied by means of a hydraulic jack in a pressing frame, or by means



A.



B

FIG 18, A and B—K D Photographs, May 4, 1944, showing moulages with the wax model in place and out of position

of a large vise. The pressure must be applied gradually and evenly, allowing the metal to stretch. After closing the flask slightly, when molding has begun, it is wise to remove the plate from the flask to inspect it for wrinkles in the metal near the borders. The edges of excess metal may be trimmed off and if wrinkles are developing, they should be hammered out with a large ball peen hammer, working in the excess metal. A small hole may be drilled at the apex of the wrinkle and the wrinkle cut out producing a slit if it cannot otherwise be eliminated. By replacing this plate in the flask and press and gradually increasing the pressure until the flask is closed, periodically inspecting the plate and trimming the edges until the exact contour of the die is obtained, a very accurately fitting plate is accomplished. No great amount of work should be necessary with the hammer if the flasking operation is done properly and the initial plate is allowed to "stretch" while being securely locked at its margins. The plate should not be heated or annealed to mold it as it becomes brittle due to oxidation in open air. In the making of smaller plates, it is advantageous to make the die and counterdie of lead and zinc within a dental flask. This provides an excellent swaging surface of great strength, although the stone is entirely satisfactory if an adequate flask is provided. The method* utilizing the female die and a heavy rubber pad in pressing cylinder gives excellent results. However, the procedure just outlined affords quite satisfactory plates with a minimum of equipment and expense. After a satisfactory swaging of the plate has been accomplished, the edges are prepared to a smooth contour, having the plate slightly oversize so that it can be trimmed by the surgeon at the operating table. The plate is then boiled in concentrated hydrochloric acid for twenty minutes to clean it thoroughly. It is sterilized by ordinary autoclaving. (Fig. 19.)

Where a plate is made to close a defect tightly, small holes of 3 mm. diameter are drilled in the body of the plate to allow escape of fluid from beneath the plate in the skull so that it can be aspirated easily from beneath the galea.¹⁴ This can be used to good advantage also should an infection supervene with the plate in place so that penicillin could be injected beneath the galea and so reach both sides of the plate.¹¹ The perforations also allow granulation tissue to grow through the plate between the dura and galea and so obliterate the dead space beneath the plate and help to anchor it securely in its bed.

In carrying out the second stage operation for the insertion of the tantalum plate, the patient is prepared as for an osteoplastic craniotomy under general anesthesia. The scalp is turned down over the defect, care being exercised to stop all oozing from the galea at the start so that an absolutely dry field is insured when closing the flap. The periosteum along the edge of the bone defect is then stripped back about one-half inch and the tantalum plate placed over the defect as a trial fit. The plate is cut down to proper size with a heavy curved (blunt uterine) shears, allowing an overlaying margin of about one-fourth inch. A convenient method of obtaining an accurate size plate is to mold a piece of moistened cottonoid sheet into the bony defect

*Method suggested by the Fansteel Metallurgical Corp., Chicago, Ill.

and then cut out the pattern of the defect. This pattern is then placed onto the underside of the plate, which can then be trimmed to correct size. With the plate cut to proper size, it is replaced on the skull and its margin marked with a sterilized lead pencil onto the skull. Then by means of a bone chisel 2 mm. wide (long bevel), a channel is cut through the outer table of the skull about 1 mm. deep, and the intervening outer table between the defect and this channel chiseled out by means of a bone chisel 5 mm. wide. This forms a ledge into which the plate fits securely and so prevents lateral movement. The plate can then be anchored in its bed by one of two methods. Small triangular swedges made of tantalum (.020 inch thick) can then be driven over the edge of the plate into the bone ledge in the same manner that a pane of glass is fastened into a window frame. The technique that we prefer is that of anchoring the plate by tantalum wire (.020 diameter) in four or six places, depending on the size and shape of the plate. We feel that the



Fig. 19.—K.D. Photograph, May 18, 1944, of finished tantalum plate prior to its insertion.

plate is fixed more securely by this latter method and by turning the wire-twist ends down into the skull perforations, a very smooth fixation is effected, leaving no irregularities to be palpated through the scalp. The field is then dried thoroughly and the scalp closed in two layers with fine silk sutures. A fairly heavy compression dressing is then applied to prevent fluid accumulation about the plate. Nevertheless, on the first postoperative dressing done in twenty-four to thirty-six hours, a brain needle is passed beneath the galea and about 10 to 20 c.c. of serosanguineous fluid can be removed. The patient can usually be allowed out of bed on the third day and the sutures removed on the fifth day postoperatively. Healing is sufficiently complete in one month that the individual can carry on any average activity.

The two patients who had tantalum plates inserted into the forehead found that their hats fit them as well after operation as before they became ill. The patient with the largest plate submitted himself for placing of ice packs to the forehead to determine effects of extreme

low temperature on the plate, and he experienced no great or peculiar discomfort. He has recently been exposed to the hot sun also without any unusual effects.

SUMMARY AND CONCLUSIONS

1. Osteomyelitis of the frontal bone, secondary to sinus infection, is a serious surgical disease because of the difficulty in limiting spread of the infection. The causative organism in most cases is the *Staphylococcus aureus* or *albus*.

2. Penicillin is an excellent bacteriostatic agent in these cases so that the infectious process is brought under control rapidly, permitting early surgical removal of the diseased bone. Penicillin is not a substitute for surgery in this condition.

3. Surgical excision of the diseased bone is necessary in most instances. It can be done as soon as the infection is controlled by penicillin, at which time primary closure of the scalp is a feasible procedure. This method of treating frontal osteomyelitis is revolutionary and is the treatment of choice.

4. A small percentage of patients may recover under penicillin alone, but their progress must be observed carefully lest the process flare up again at a later date and/or the patient become penicillin-resistant which would eliminate its future use in that particular infection.

5. The correction of the postoperative defect in the frontal bone and glabella region is carried out preferably at a secondary operation, at least three months after the primary operation. This allows complete eradication of the infection in the frontal sinus region as well as complete closure of the nasofrontal duct by granulation tissue.

6. We have found tantalum plate (.015 inch thick) very satisfactory for use as an alloplastic method in the restoration of the normal contour of the frontal bone. This metal can be molded or pounded in the cold state and made to cover the defect smoothly and solidly. The plate causes no discomfort to the patient.

7. A method of preparation of tantalum plate, using dental materials, and its insertion to cover a large defect in the frontal bone has been described.

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RADICAL DUODENOPANCREATECTOMY

REPORT OF A SUCCESSFUL RESECTION OF A CARCINOMA OF A DUODENAL DIVERTICULUM INVOLVING THE HEAD OF THE PANCREAS

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(From the Clinic)

SURGICAL lesions of the pancreas have been receiving increasing attention within the past few years. Removal of a portion of or even the entire gland has been found to be compatible not only with life but even with good health. Many of the problems concerned with the metabolism of fats, proteins, and carbohydrates have undergone and are undergoing intensive study, resulting in drastic changes in many instances in our concept of the relationship between the pancreas and our body economy. Some of the physiologic properties of this organ are still shrouded in doubt, but on the whole no more brilliant discoveries in the entire annals of medicine can be cited than those related to the functions of the pancreas.

It may be of interest to mention briefly a few of the outstanding contributors who have increased our knowledge of this organ.

To Bernard,¹ in 1856, goes the honor of being the first to classify the actions of the pancreatic juice in food digestion.

Langerhans,² in 1869, while still a medical student in Berlin, gave the first accurate histologic description of the pancreas and to him goes the distinction of first differentiating between the cells, which have subsequently borne his name, from those of acinar tissue.

Von Mering and Minkowski,³ in 1889, first demonstrated the exact role of the pancreas in carbohydrate metabolism and its relationship to diabetes as demonstrated experimentally in pancreatectomized animals.

To Banting and associates,⁴ in 1922, goes the honor and credit and gratitude of thousands, now and yet to come, for the brilliant discovery of insulin and its production in a form to be used in successfully controlling diabetes.

These are the men who were the outstanding contributors in the earlier study of the metabolic activities of the pancreas and who laid the groundwork which subsequently made it possible successfully to approach this organ surgically. One can state with a considerable degree of pride that most of the

pathologic and surgical contributions to this field have been made by Americans, or at least by those residing in the Western Hemisphere.

In 1889, Fitz⁵ of Boston gave the first clear and concise description of the clinical entity of acute pancreatitis and Opie,⁶ in 1903, was the first to observe a stone obstructing the ampulla of Vater and to surmise that bile shunted into the pancreatic ducts was a likely etiologic factor in acute pancreatitis.

Harris⁷ of Atlanta, undoubtedly a keen clinical observer, in 1924, drew attention to the close similarity of the picture of insulin shock as observed in the overtreated patient with diabetes to the syndrome of hunger, weakness, tremor, tachycardia, convulsions, and coma associated with a low blood sugar level observed in those who do not have diabetes and relieved by carbohydrate administration. He suspected, but did not prove, that this clinical picture resulted from hyperactivity of islet pancreatic tissue.

It remained for Wilder and associates⁸ of the Mayo Clinic, in 1927, and W. J. Mayo as the surgeon to demonstrate a carcinomatous lesion of the islands of Langerhans as the etiologic factor in the causation of spontaneous hyperinsulinism.

In 1929, Howland and others⁹ reported the first successful removal, by Graham of Toronto, of a tumor of islet tissue from a patient with symptoms of hyperinsulinism.

These observations and experiences have led to a quickening interest in this new field of endocrine surgery so that now the literature is replete with reports of many brilliant successes following this method of therapy.

Surgery of the malignant acinar growths involving the pancreas, more particularly those of the head, in association with the common duct, the duodenum, and the papilla of Vater, is not a new concept, since Kausch¹⁰ in 1912, reported the first successful removal of such a lesion.

Halsted,¹¹ in 1899, had successfully dealt with a lesion of the ampulla of Vater by resection of the duodenum with end-to-end anastomosis and re-implantation of the common and pancreatic ducts into the duodenum.

However, one need but recall the words of Sir Berkeley Moynihan¹² as late as 1926, to realize what strides forward have been made in pancreatic surgery in comparatively recent years. At this time he stated, "The radical treatment of malignant disease of the pancreas by the surgeon can hardly be said to exist," and, speaking of the attempts that had been made up to this time, "They all serve to show that the mechanical difficulties of the operation are well-nigh insuperable and that if boldness and good fortune are the operators' gifts, the result to the patient hardly justifies the means."

It has remained for those interested in the subject in recent years to make such procedures sufficiently safe and successful to be of practical significance.

Whipple,¹³ in 1940, was the first to carry out successfully a one-stage radical duodenopancreatectomy. To these later surgeons and investigators who have aided in making such a procedure one that can be looked upon with favor, one must add the names of Dragstedt, Brunschwig, David, Hunt, Cattell, and many others.

Not only has improved knowledge concerning the physiologic activities of the pancreas been a contributing factor to these developments but all the other improvements that have added to the safety of surgery in general. The means at our disposal of preventing and treating shock, the use of vitamins, particularly vitamin K, in these patients who are usually jaundiced from obstruction of the common duct, the use of Wangenstein suction, the prevention

of infection by sulfonamides and penicillin, and improved methods of anesthesia are the important advances made in recent years.

Since at least a working familiarity with the known physiologic functions of the pancreas is a prerequisite to the intelligent application of surgical principles in pancreatic surgery, a brief résumé of this subject is presented at this time.

The sole functions of the pancreas, as far as are known at present, are in connection with digestion, absorption, and metabolism of fats, starches, and proteins by the medium of its internal and external secretions.

The amount of pancreatic secretion depends upon variable factors and fluctuates between 500 and 1,500 c.c. daily. It is a clear alkaline solution with a pH varying between 8.71 and 8.98, the alkalinity being largely due to the presence of sodium carbonate. Its digestive action depends upon the presence of three groups of enzymes; proteolytic, amalytic, and lipolytic in nature. The proteolytic enzyme is secreted in a zymogen or proenzyme form, trypsinogen, which is activated or converted to trypsin by something contained in the enteric mucous membrane. Pavlov supposed this substance to be an enzyme and called it kinase or enterokinase, which by hydrolytic action upon the trypsinogen converts it into trypsin. Trypsin, together with another enzyme, erepsin, acts to split the protein molecule into amino acids.

The carbohydrate-splitting enzyme, amylase, hydrolyzes starch, producing maltose and acrodextrin, which are further broken down by the maltase of the intestinal secretions to form dextrose.

Fat is hydrolyzed and saponified by lipase and broken down in the process into glycerin and fatty acids, being aided and abetted by the presence of bile.

The principal internal secretion of the pancreas, as is well known, arises from the beta cells of the islands of Langerhans, consists of insulin, and is responsible for the metabolism of carbohydrates.

Recently, Dragstedt¹⁴ has, in his opinion, though this has not been concurred in by all investigators, demonstrated another internal secretion of the pancreas to which he has given the name of lipocaic because, as he says, it has to do in a general way with the utilization of fat. It had been his observation, along with others, that completely depancreatized dogs did not live long even though their diabetes was satisfactorily controlled with insulin. At death the most obvious autopsy change noted was extensive fatty infiltration and degeneration of the liver. Addition of raw pancreas to the dogs' diet prevented or diminished markedly these degenerative liver changes and resulted in longer survival of such animals. This was not noted when the animals were fed pancreatic secretion. A fat-free alcoholic extract of pancreas was found to have the same beneficial effect, so it was concluded that a new and hitherto undescribed internal secretion or hormone had been isolated, possibly arising from the alpha cells of the islands of Langerhans. A few scattered reports have appeared in the literature indicating that the use of lipocaic in human diabetics has been beneficial in preventing fatty degeneration of the liver and cardiovascular changes so common in this condition.

The effect of complete occlusion of the pancreatic ducts on the incidence of fatty infiltration of the liver in experimental animals has yielded conflicting results in the hands of different workers. As is pointed out by Dragstedt, animals with pancreatic fistula do not develop fatty livers when the pancreas remains normal, indicating that fatty infiltration of the liver is not due to the absence of pancreatic juice from the intestinal tract. The presence of a moderate

degree of fatty infiltration of the liver in a minority of the animals following ligation of the pancreatic ducts seems, therefore, to be due to the atrophy of the pancreas that takes place in these animals. There is evidence that this atrophy affects the islets as well as the parenchyma in some cases. These experimental observations may help to account for the clinical variations that have been noted following surgery on the pancreas, and will be referred to later in this paper.

Tests for acute and chronic inflammatory lesions of the pancreas have within recent years been of considerable practical importance to the clinician. In the early stages of acute pancreatitis, within the first three to five days to be exact, lipase and amylase determinations in the blood and amylase in the urine usually reach high levels, sufficient to be of importance in the differential diagnosis between pancreatitis and other acute abdominal lesions. Comfort and Osterberg,¹⁵ Whipple,¹³ Fennel,¹⁶ and others have called attention to this valuable laboratory aid. In chronic pancreatitis these determinations have not been found of value but other methods have been elaborated.

In 1902, Bayliss and Starling promulgated the secretin theory to account for the flow of pancreatic juice. It was their belief that acid chyme coming in contact with the mucosal cells of the duodenum and upper intestine changed a prosecretin into secretin. Secretin being absorbed into the blood stream stimulates the pancreas to function. In 1937, Agren and Hammersten¹⁷ isolated the hormone secretion in crystalline form, which apparently is specific for pancreatic cells with the exception that it may augment bile secretion. When injected intravenously this substance produces a great increase in flow in the secretion of the normal pancreas. In 1939, Lagerlof,¹⁸ using a double lumen tube, one being passed through the pylorus into the duodenum and the other remaining in the stomach, was able to aspirate pure pancreatic juice in large amounts following injection of secretin intravenously. In chronic inflammatory lesions of the pancreas this response is markedly diminished, and in obstructive lesions is absent. In jaundiced individuals this method of examination has been found of value in differentiating obstructive lesions of the common and hepatic ducts from those in the region of the papilla of Vater and head of the pancreas, obstructing both the biliary and pancreatic outflow.

According to Whipple,¹³ mecholyl or methylacetylcholine has further elaborated the duodenal determinations of pancreatic ferments. Secretin, which is a hormone, increases the volume and alkalinity of pancreatic juice, while mecholyl, acting through the vagus, increases the concentration of the ferment without increasing the volume and alkalinity and is a more accurate index of the activity of acinar tissue than of the obstruction of the flow of the pancreatic juice.

This would seem to be the opportune time to discuss more fully some of the observations that have been made clinically and experimentally when the external secretion of the pancreas has been abolished by resection of the head of the pancreas and closure of the remaining stump and when both the internal and external secretion (hormone and enzyme action of the organ) has been deleted by its complete extirpation. Many of the problems associated with surgery of the pancreas were formerly of interest only to the physiologist. Much of our knowledge of the pancreas has been derived experimentally from laboratory animals, particularly the dog, but unfortunately with accumulating clinical experience the correlation with human physiology is not always applicable. However, this method has been of inestimable value. For instance, it was formerly thought that removal of the duodenum was not compatible with life. Drag-

stedt and co-workers,¹⁹ in 1918, first successfully removed entirely this structure from the dog and this observation has subsequently lent courage to those attempting the procedure in man.

Until recently, complete removal of the pancreas in man had not been successfully accomplished. While it yet remains to be demonstrated that this is a procedure of practical importance, sufficient encouraging data have been accumulated, both experimentally and clinically, to justify further consideration and investigation.

As we have previously pointed out, depancreatized dogs do not survive long even if the resulting diabetes is adequately controlled by insulin administration. Autopsies have shown a remarkable accumulation of fat in the liver of such animals. Oral administration of from 100 to 200 Gm. of raw pancreas daily suffices to prevent this fatty change and permits these dogs to survive for long periods of time and perhaps indefinitely when their nutritional needs are adequately supplied. Raw pancreas furnishes lipocae previously mentioned.

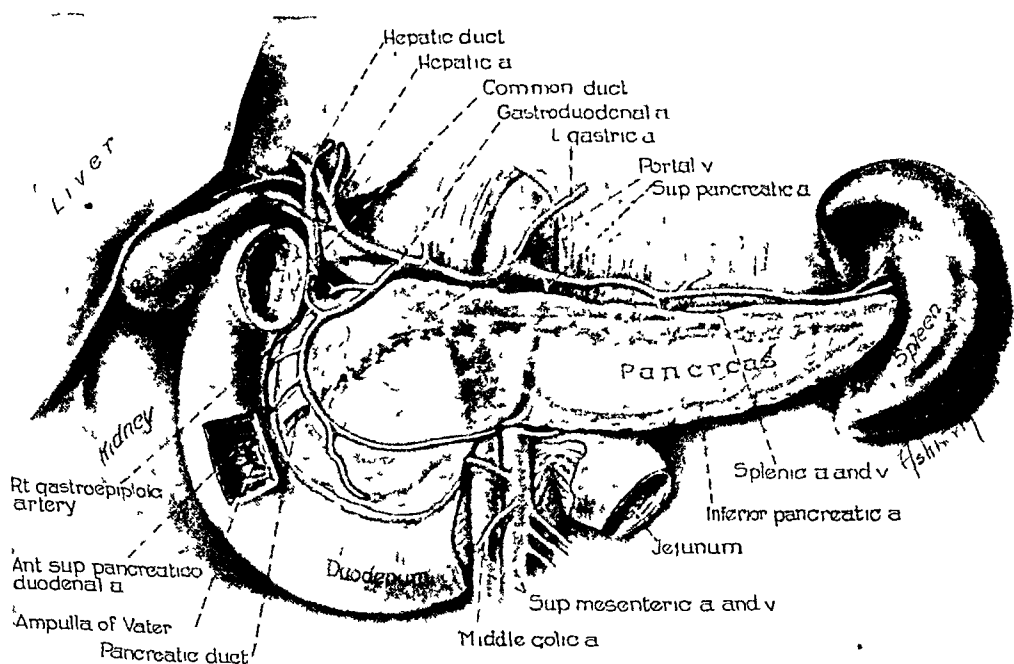


Fig 1.—Normal anatomy of the duodenopancreatic region.

In the human being, so far as I have been able to determine, only two or three total pancreatectomies have been recorded.

Rockey,²⁰ in 1943, reported practically a total pancreatectomy for carcinoma, the patient surviving for fifteen days. Autopsy revealed less than 1 Gm. of pancreatic tissue remaining.

The second case was reported in February of 1944 by Priestley and associates,²¹ from the Mayo Clinic, and is of special interest because the patient was alive and well at the end of sixteen months. The patient presented the typical picture of hyperinsulinism and at operation no pancreatic tumor could be identified. The entire gland, which weighed 80 Gm., was removed and subsequently an islet tumor 2 by 5 by 5 mm. was found to account for the symptoms of hypoglycemia.

It has been found both experimentally and clinically that diabetes occurs only when over 90 per cent of the pancreas is removed. This diabetes is severe

and necessitates daily administration of from 60 to 100 units of insulin in the human being to effect control. Diabetes in totally depancreatized animals is less severe and is more easily controlled than that occurring following partial resection. This was found to be the case in the two total removals in human beings. Stabilization was reached in Rokey's case at less than 27 units of insulin daily and in the case reported by Priestley the highest blood sugar level was 341 mg. per cent the morning after operation and the greatest total units of insulin administered for a single day were 66. From about the fifth post-operative day on, control of the diabetes was obtained by a single daily subcutaneous injection of protamine zinc insulin and regular insulin, averaging 30 units, the ratio being from 1 unit of protamine zinc to from 1 to 2 units of regular insulin.

In an attempt to offset the fatty changes noted in the depancreatized experimental animal the patient was fed a diet rich in choline. Fifty grams of cottage cheese of high protein content were considered adequate to prevent such changes. The excellent health of the patient sixteen months after total removal of the pancreas was thought to be good evidence that such change had not developed. From rather extensive metabolic studies no disturbance in carbohydrate digestion could be detected. From 35 to 70 per cent of the ingested fat and from 25 to 55 per cent of ingested nitrogen could be accounted for in the feces. In spite of this loss a positive nitrogen balance occurred and the patient has remained in excellent health with no evidence of deficiency of lipocaine.

Observation of many more human beings in whom the entire pancreas has been removed with favorable results will, of course, be necessary before this procedure can be considered to be of practical significance. However, this single encouraging report should do much to stimulate further interest in this subject.

In order further to present various aspects, both physiologic and technical, associated with the operation of radical duodenopancreatic surgery, it seems desirable to present the following case report and follow this by a discussion of the various problems that arose in the conduct of the case.

CASE REPORT

A 44-year-old Chinese man was first seen in consultation with Dr. K. C. Chock, July 7, 1944. The onset of symptoms occurred five months previously with upper abdominal pain and discomfort associated with diarrhea. There had been as many as six to eight stools daily and the patient had noticed the presence in them of droplets of oil, particularly following ingestion of fatty foods. During this time there had been a loss of fifteen pounds in weight. Physical examination was essentially negative except for moderate tenderness and muscle spasm to the right and above the umbilicus. It was thought that an indefinite mass could be palpated in this area. Urine examinations had intermittently shown the presence of sugar. However, the blood sugar level on June 6 was 89 mg. per cent and three days later a glucose tolerance test showed: blood sugar 102 mg. per cent, urine negative; blood sugar 166 mg. per cent, urine negative; and blood sugar 169 mg. per cent, urine showed a trace of sugar.

July 1, feces examination for determination of pancreatic enzyme deficiency showed amylase measure of digestion 400 units (normal 30,000 to 60,000). Gastrointestinal x-rays revealed a large space-taking lesion involving the region of the head of the pancreas as shown by the wide arc made by the duodenum.

Exploration of the abdomen at this time was advised, but was refused.

The patient was not seen again until Oct. 3, 1944, approximately eight months after the onset of the trouble. Symptoms remained essentially the same. He had lost five pounds more in weight, and the fatty diarrhea continued. A mass was now definitely palpable. It was significant that the patient had not had clinical evidence of jaundice at any time.

The patient was admitted to the Queen's Hospital for further study and operation. An attempt at gall bladder visualization by oral dye was unsuccessful. Intravenous pyelograms were negative.

Blood count showed: red cells 4,600,000, white cells 3,200, polymorphonuclears 48 per cent, lymphocytes 45 per cent. Red cells were normal. Hemoglobin was 81 per cent (12.2 Gm.).

Plasma protein was 6.7 mg. per cent, nonprotein nitrogen was 35 mg. per cent, fasting blood sugar was 138 mg. per cent, Wassermann and Kahn were negative.

The patient was operated upon Oct. 5, 1944, under cyclopropane-ether anesthesia. The duration of the operation was three hours and forty-five minutes. A right rectus muscle-splitting incision was made and later, to gain better exposure, the incision was carried transversely to the left above the umbilicus. A mass occupying the head of the pancreas was encountered that seemed confined to this area and for this reason was considered probably operable. Exploration retroduodenally by way of an incision through the peritoneum to the lateral side of the duodenum substantiated this opinion.

The common duct was temporarily ligated and severed at the upper margin of the duodenum. The gastrohepatic ligament and the transverse mesocolon were severed to enable the removal of the distal two-fifths of the stomach. The jejunum was severed just beyond the ligament of Treitz. The tumor, which was intimately adherent to the portal and superior mesenteric veins, was carefully dissected free of these structures. In so doing the portal vein was opened. Bleeding was controlled by plugging the opening with the index finger of the left hand while repair of the opening was made with fine interrupted silk. The duodenum was fished out from beneath the superior mesenteric vessels, the pancreas was severed wide of the tumor, and the specimen, which consisted of the distal two-fifths of the stomach, the distal one-third of the common duct, the entire duodenum, and the head and body of the pancreas containing the tumor were removed.

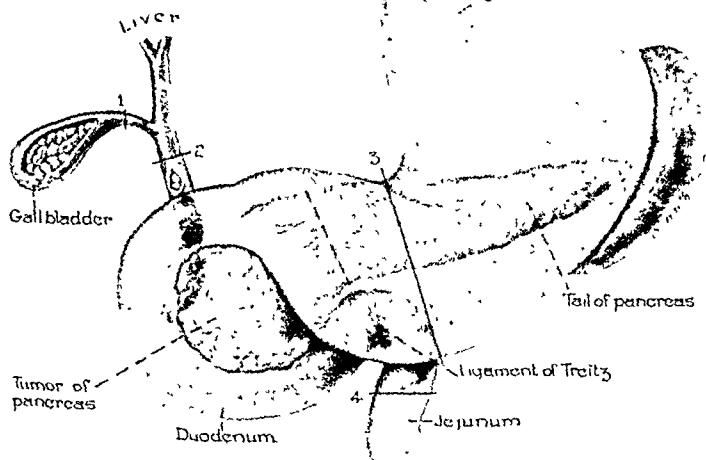


Fig. 2.—Showing the pathologic processes and the site of resection of the gall bladder, the common duct, the duodenum, the pancreas, and the stomach.

The remaining portion of the pancreas was quite firm and indurated and the duct dilated, easily admitting the end of a hemostat. The distal end of the severed jejunum was brought up behind the colon and fitted over the end of the pancreas, suturing the serosa of the jejunum to the side of the pancreas with two continuous rows of atraumatic chromic catgut and one row of interrupted silk. The same technique was used subsequently in the anastomosis of the common duct and stomach, to the jejunum. The posterior layer of peritoneum of the lesser omental sac was utilized in reinforcing the anastomosis of the duodenum and pancreas and lent itself to this purpose quite satisfactorily.

The common duct was approximately twice its normal size in diameter. The gall bladder was filled with stones. It was removed. Two small stones were found in the common duct and these were removed. No others could be found by scoop or following irrigation. The duct was anastomosed to the jejunum over the proximal flared end of a short segment of a No. 16 rubber catheter. Beyond this the stomach was anastomosed end-to-side to the jejunum. Three soft rubber tissue drains were inserted, one into the region of the common duct anastomosis and the others to the region of pancreatic anastomosis, and the incision closed.

During the operation and immediately following, the patient received 2,500 c.c. of blood. He stood the operative procedure well.

The patient was known to be sulfa-sensitive. To help offset infection he was given postoperatively 20,000 units of penicillin every three hours for forty-eight hours. Wangenstein suction was continuous for four days, then intermittent for forty-eight hours. He was given 1,000 c.c. of lactate Ringer's solution containing 10 per cent glucose plus 100 mg. of cevitamic acid, 20 mg. vitamin B₁, and 100 c.c. of 15 per cent amino acids every eight hours, for four days or during the time of Wangenstein suction.

Recovery was uneventful except that beginning on the eighth postoperative day there was considerable drainage of bile for about four days, probably due to leakage through the stump of the cystic duct. So far as could be told there was no drainage of pancreatic secretion. There was no irritation of the surrounding skin about the drain and the wound healed kindly.

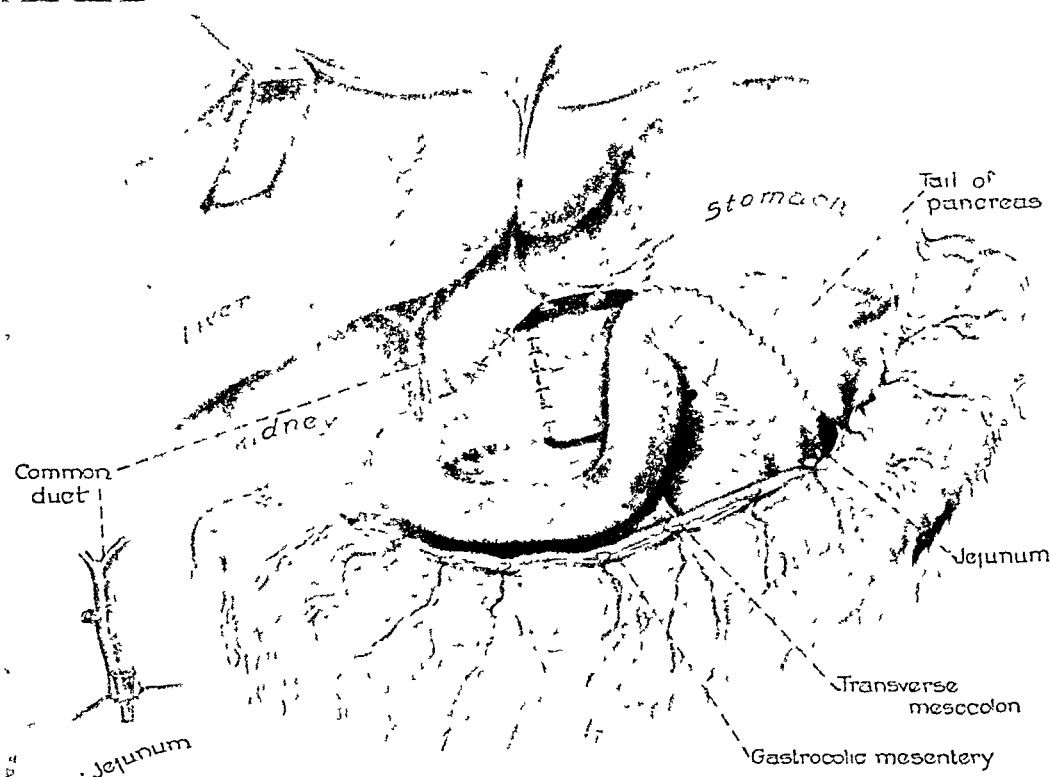


Fig. 3—Showing the anastomosis of the pancreas, common duct, and stomach to the jejunum.

Pathologic Report.—*

Gross: The specimen consisted of a portion of stomach measuring 12 cm. in length along the greater curvature. The mucosal markings were normal except for one small area which was raised and measured about 3 mm. in diameter. It was confined to the mucosa. There was also a gall bladder measuring 15 cm. in length. It contained bile and about sixteen calculi of mixed type, varying from 3 to 15 mm. in diameter. The wall of the gall bladder was somewhat edematous. Separately was a portion of small intestine measuring about 30 cm. in length, which was stretched over a tumor mass measuring 10 cm. in diameter. There were three large ulcerated areas which showed perforations into this mass, so that the lesion grossly was either a large diverticulum or a tumor which had ulcerated into the intestine. The ulcerations measured approximately 2 by 1 cm., another 3 cm., and the other 2.5 by 1.5 cm. Thick mucus and tumorlike tissue protruded through the ulcerations. When the specimen was incised, it showed what appeared to be a large amount of adenomatous tissue and mucus, with several long glandular pockets like that of a diverticulum, but in addition there were foci of gelatinous material closely resembling carcinoma. There was a fibrous wall surrounding the entire mass, in part at least of inflammatory origin.

*By Dr. Sumner Price, Pathologist, The Queen's Hospital, Honolulu.

Microscopic: Histologic examination of the gall bladder showed a subacute exudative inflammatory reaction, with slight hypercholesterosis of the mucosa of the gall bladder. There was a well-marked cellular inflammatory reaction involving the mucosa, which extended down into the muscularis. There were a number of eosinophiles present, as well as a considerable number of polynuclears and lymphocytes. Examination of the stomach wall showed



Fig. 4.—The amount of stomach remaining after resection.



FIG. 5.—The gross specimen, showing probe in the common duct, the entire duodenum, the tumor involving the head of the pancreas, the gall bladder containing stones, and the resected stomach.

a small, benign polypoid adenoma, and at one point there were a few glands deeply imbedded beneath the muscularis mucosa which suggests that there was probably present a small unrecognized diverticulum of the gastric wall. A section from the duodenum showed a large diverticulum wall presenting edematous and hypertrophied villi. There was a well-marked inflammatory reaction present as well as a large amount of mucus. There were numerous glandular cells distributed throughout the wall of the diverticulum and separately there was definite evidence of an early low-grade adenocarcinoma involving the wall, showing large pockets of broken glandular tissue, with mucinous exudate, which coincided with the gross appearance of the lesion. However, new sections will have to be made from the capsule of this mass to determine the degree of infiltration of the surrounding structures and a subsequent report will be filed.



FIG. 6.—Showing the histologic structure of the tumor.

Diagnosis: Small adenoma of the mucosa of the stomach. Questionable diverticulum of the stomach. Large ulcerated diverticulum of the duodenum, with secondary adenocarcinoma.

Supplementary Report.—Histologic examination showed a thickened wall of a diverticulum from the duodenum, with foci showing adenocarcinoma. There was no question as to whether the lesion was from a diverticulum since the pockets contained villi like those found in the duodenum. In the thickened wall were found also a few elements of pancreatic tissue with general atrophy of the parenchyma. However, there was no evidence that the pancreas played any role in the tumor, and this atrophic change was a frequent finding in inflammatory and obstructive lesions in the pancreas, and had no relationship to the tumor. Separately there was a lymph gland found attached to the specimen and it presented no evidence of any metastases.

Diagnosis: Diverticulum of the duodenum with adenocarcinoma.

The patient was discharged on the thirtieth postoperative day, having remained in the hospital longer than necessary because of home conditions. The urine remained free of sugar and two months following operation the blood sugar was 106 mg. per cent. Several urine and blood amylase determinations have been within normal limits.

In the majority of lesions of the head of the pancreas in which radical resection is indicated, there is an associated jaundice due to common duct obstruction. The question then arises as to whether the operation should be done in one or two stages. With the use of vitamin K there is undoubtedly less danger to the one-stage procedure but the majority opinion, I believe, favors the cor-

resection of biliary obstruction as a preliminary procedure, particularly in debilitated subjects. Implantation of the common duct into the jejunum holds preference over other procedures. Objections to the two-stage method are the likelihood of increasing technical difficulties subsequently by adhesions and the increased danger of two anesthetics and two operative procedures, to say nothing of the objections by the patient. Since jaundice was not present in the case we are presenting, this question did not come up for consideration.

Why was two-fifths of the stomach resected?

It is well known and becoming more firmly established in the minds of those doing gastric surgery that anastomosing the jejunum to an intact stomach is followed in a high percentage of cases by gastrojejunal ulcer. These data, of course, have been accumulated following gastroenterostomy for duodenal ulcer where the gastric acidity is almost universally abnormally high. Whether this high percentage of ulcer would occur without an ulcer diathesis, of course, no one knows, since there has been no series of cases where this has been done. However, in supposedly normal stomachs in the experimental animal (the dog), again it has been shown that such ulcers do develop particularly when the external secretion of the pancreas has been eliminated from the intestinal canal.

The experiments of Mann and Williamson,²² Elman,²³ and Dragstedt and associates¹⁹ have shown some interesting observations in this respect. With total pancreatic fistulas, almost 100 per cent of animals probably would develop duodenal ulcers unless large amounts of alkalis were administered. This presumably is due to the absence of alkaline pancreatic secretion neutralizing the acid gastric content. In depancreatized dogs there is almost complete immunity to ulcer, Dragstedt reporting less than one dozen cases in 400 such animals. Animals with ligated pancreatic ducts occupied a midground.

It is difficult to understand why diversion of the external secretion of the pancreas from the intestinal canal is so commonly associated with duodenal ulcer while complete removal of the pancreas is so rarely followed by ulcer. Perhaps further elucidation of these findings may throw additional light on the etiology of peptic ulcer in man. Suffice to say that removal of the distal two-fifths of the stomach in our case was done in order to remove that portion of the stomach that supposedly stimulates the acid-secreting cells of the fundus. By this procedure we hope to decrease the normal gastric acid secretion and help prevent the subsequent development of a gastrojejunal ulcer.

The next question—Why was the remaining portion of the pancreas inserted into the open end of the jejunum?—can be answered by saying that we hoped to preserve some of the external secretion of the pancreas. The necessity for attempting to do this is at the moment a debatable one. Most of the data at present have been obtained from the experimental animal, though information from human beings is being rapidly accumulated following radical operations on the pancreas.

Without exception, the exclusion of pancreatic juice from the intestinal canal in laboratory animals causes the appearance of large amounts of undigested fat and protein in the feces as shown by Pratt, Ralli, and others.^{24, 25} This imperfect absorption of fat cannot be accounted for entirely through failure of digestion of fat since a similar though less severe excretion of fat was found when animals were fed on fatty acids.

In human beings a similar though usually less severe disturbance in digestion and absorption of fats and protein is noted when the head of the pancreas is resected and the remaining portion is left unconnected with the gastrointestinal canal. Under these conditions there occurs a fatty diarrhea, steatorrhea,

the presence of undigested meat fibers showing transverse striations creatorrhea, and an increase in nitrogen content of the stool azotorrhea.

Whipple and co-workers²⁶ found, in three patients with complete duodenectomy and total exclusion of the pancreatic juice from the gastrointestinal tract, fat digestion of 80 to 85 per cent of a carefully measured fat intake, and, in a patient who came to autopsy nine months after radical operation, fatty degeneration of the liver was not found. In only one of the five patients surviving for periods of five to twenty-eight months after radical operation have they found a disturbed fat metabolism. Rekers, Paek, and Rhoads,²⁷ on the other hand, did metabolic studies on a patient who had undergone a resection of the duodenum and head of the pancreas and ligation of the pancreatic ducts. Six supposedly normal individuals were used as controls. In this patient it was found that from 87 to 95 per cent of fat and from 39 to 45 per cent of nitrogen ingested was lost in the feces. They found that the addition of amino acid nitrogen to the diet did not increase significantly the fecal output so concluded that the *digestion of protein and not the absorption was impaired*. Daily ingestion of 6 Gm. of lipocaine was without significant effect, but the daily administration of 25 Gm. of the external secretion of the pancreas in the form of enteric coated pancreatin* caused a fall in the feces of the amount of fat ingested from 91 to 32 per cent and nitrogen from 44 to 3 per cent of that ingested. They further found that an increase in the protein content of the diet resulted in increased absorption of fat, while an increase in the fat content resulted in an increase of fat absorbed but no lessening of fat lost.

It has been found that on an unregulated diet considerable variation in fat excretion will be found in different individuals and even in the same person from day to day.

Fowweather²⁸ analyzed the stools of eighty hospital patients without evidence of gastrointestinal disease and arrived at the following conclusions:

1. Any specimen in which the total fat amounts to more than 25 per cent of the total dry matter is probably abnormal.
2. Any specimen in which the neutral fat exceeds 11 per cent of the total dry matter or 55 per cent of the total fat should be suspected of showing evidence of deficient fat splitting.
3. Any specimen in which total split fat (that is, the sum of soap fat and free fatty acid) exceeds 16 per cent of the total dry matter or 75 per cent of the total fat should be suspected of showing evidence of deficient fat absorption.

Kolmer²⁹ states that normally the daily average of fecal nitrogen varies from 1.5 to 2.3 Gm. and lipids from 7 to 10 Gm.

It has also been shown that even on a fat-free diet there is a daily excretion of about 2 Gm. of fat, the composition of which is very similar to that of blood lipids and it is now generally believed that at least a fraction of the fecal lipids is derived from the blood and is secreted into the small intestine.

Bodansky and Bodansky³⁰ state that on a Schmidt diet which consists of the daily ingestion of 118 Gm. of protein, 111 Gm. of fat, and 119 Gm. of carbohydrate, the normal individual will absorb over 94 per cent of the fat and over 92 per cent of the nitrogen. It is further pointed out in their studies of pancreatic steatorrhea that the maintenance of nitrogen balance may be difficult since as much as 80 per cent or more of intake of nitrogen may be excreted in the stools and that a combination of high protein intake and pancreatic enzymes are often of no avail in preventing imbalance.

*Parke, Davis & Company, Detroit, Mich.

While it would seem advisable, if possible, from the data presented, to preserve the external secretion of the pancreas in order to prevent steatorrhea, creatorrhea, and azotorrhea, and perhaps complications that we at present are unfamiliar with that may arise in cases that are observed longer, it has not been the universal custom, by any means, of surgeons to do so.

Brunschwig³¹ states, after an experience with eight one-stage pancreatoduodenectomies, that the successful anatomic implantation of the pancreatic stump into the bowel in man has not yet been demonstrated to approach normal or appreciable secretion of pancreatic juice into the bowel and that he will continue to close the stump of the pancreas until it is proved that successful transplantation can be done.

Cattell,³² on the other hand, has reported fifteen radical operations and he has been a consistent advocate of implanting the remaining stump of the pancreas into the jejunum. On his recent visit to Hawaii he stated that he had now done twenty-one such operations and still believed that the remaining pancreas should be anastomosed to the jejunum.

Child³³ reported a one-stage radical pancreaticoduodenectomy in which the stump of the pancreas was implanted into the open end of the jejunum. From secretin tests before and after operation, he concluded that there was approximately one-sixth of the normal pancreatic secretion into the intestine. The patient manifested no abnormality in fat digestion, following operation.

According to Hunt,³⁴ Tenani, in 1922, and he, in 1941, successfully implanted the stump of the pancreas into the open end of the jejunum. He stated that preservation of the external pancreatic secretion is desirable but that the problems of pancreatic intestinal anastomosis are great.

As Whipple¹³ has stated, "It is evident that the question of disturbed fat metabolism in a patient whose pancreas is completely isolated from the gastrointestinal tract is not as yet completely answered and only a large number of patients surviving the operation from three to five years will provide the necessary data for an accurate statement in this regard. It may be necessary to renew the efforts to re-establish the communication between the pancreas and the gastrointestinal tract in the radical removal of the ampullary and pancreatic cancers."

In the case which we have reported it would seem that some benefit has accrued from implanting the tail of the pancreas into the jejunum, though too many factors enter into the picture to permit a clear evaluation. Previous to surgery the patient was having six to eight stools daily, containing much gross evidence of fat. Subsequent to operation, bowel movements had been two to four daily without gross evidence of fat. However, he has been instructed about eating a diet low in fat and he has been receiving 20 gr. of pancreatin four times daily. Analysis of the stool on this regime has shown it to consist of 78.3 per cent water and 21.7 per cent solids. Of the solid material the total fat, made up of neutral fats, free and combined fatty acids and soaps, constituted 40.7 per cent by weight of the dried residue, a definitely abnormal amount of fat in the feces, especially in a patient on a limited amount of fat intake. Examination of the stool for meat fibers has shown their presence in large numbers and microscopic examination of the stools shows many fat droplets. Pancreatin was discontinued for one week and an increasing diarrhea was noted. Fat droplets became visible grossly and microscopic examination of the stool showed an increased number of undigested meat fibers. Determination of fat in the feces showed this made up 55 per cent of the dried residue. To date we have been unsuccessful in

obtaining lipocaic. In spite of his disturbed metabolism he is gaining strength, but not weight, and has returned part time to his original work as a radio mechanic.

Technically the implantation of the remaining pancreas into the open end of the jejunum was easily done and no resulting pancreatic fistula resulted. The use of the peritoneum of the lesser omental sac in closing over the line of anastomosis seemed to add definitely to the security of the procedure. The literature contains a number of methods of anastomosing the pancreatic ducts into the intestinal canal but the procedure used as reported would seem to have definite advantages. Placing the anastomosis proximal to the inflow of bile and gastric content, I believe, adds materially to the safety of the procedure.

The method of re-establishing the flow of bile into the gastrointestinal canal has varied but it seems to be the consensus at the moment that the safest method is to implant the common duct into the jejunum. Ligation of the common duct and implantation of the fundus of the gall bladder into stomach or jejunum have resulted in a high incidence of biliary fistula due to the ligature about the common duct blowing off or the duct not healing over. If this method is to be used the end of the common duct should be inverted before it is closed. Cholecystogastrostomy has in the past resulted in a high incidence of ascending hepatic infection, partially due, it is thought, to the vigorous gastric peristalsis forcing food particles up the ducts. If the anastomosis is made to the jejunum proximal to that of the gastrojejunostomy this complication is not so likely to occur.

SUMMARY

A brief review of the present known physiologic properties of the pancreas as related to radical duodenopancreatic resection is presented.

A case of carcinomatous degeneration of a duodenal diverticulum involving the head of the pancreas, in which successful radical duodenopancreatic resection was done, is recorded. So far as can be determined this is the first successful operation for this condition reported in the literature.

A discussion of some of the technical problems encountered in this operation is indulged in.

CONCLUSIONS

With present advances in anesthesia and pre- and postoperative care, with a clearer understanding of the physiology of the pancreas and replacement therapy, and with familiarity with certain technical procedures, radical duodenopancreatectomy can be carried out with a sufficient degree of safety to justify the procedure in selected cases and with the expectation of material benefit to the patient.

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Editorial

Anesthesia

THE possibilities in anesthesia have increased perhaps tenfold in the last ten or twelve years. The respiratory and circulatory physiology may be kept within normal limits much more certainly and much more precisely than ever before. Blood levels of oxygen and of carbon dioxide may be controlled very well and are on the way to control with still more precision. Relaxation may be obtained to the point of flaccidity with a minimum of depression of the brain and spinal cord. Respiration may be controlled to the point of quietness and absence of effort without disturbing physiologic function. All this may be done with almost an absence of the postanesthetic prostration which was expected ten and fifteen years ago and occurs too often today.

The drugs and equipment which are available to help us accomplish these things have increased year after year in number and variety. Each one has its special points of value and its special weaknesses. Each should be used to accomplish the result for which it is best suited, and should not be used in an overdose to try for an effect which another drug or method can better bring about. Thus, combined or balanced anesthesia has become the true picture of today's art. Those who use today's material and equipment in anesthesia must know it well, must be skilled in its use, and must know much more clinical physiology than the anesthetists of yesterday. Without such training they must plod along with the anesthesia of yesteryear and accept the inferior results of that time.

Do all of these improvements simplify the problems of the surgeon? Not at all, unless he entrusts them to someone in whom he has complete confidence. With the old drop-ether formula he could fairly well watch the anesthesia and direct it. With the newer drugs, equipment, and methods the results in the hands of well-trained anesthetists can be unspeakably finer and more satisfying, but it seems impossible for the surgeon, when things are not going satisfactorily, to discern what the trouble or troubles may be and help to correct them while giving adequate attention to his surgery. All he can do is to ask or demand better conditions, and only knowledge and skill at the head of the table can avoid trouble or correct it if it should appear. The use of the newer armamentarium of precision, with insufficient knowledge or skill, usually leads to more confusion and dissatisfaction.

The surgeon who has not tasted anesthesia for his surgery under the best possible auspices has something to look forward to, the value of which he perhaps does not yet appreciate. A higher quality in anesthesia than the present best is surely still to be attained and never before has there been such active effort in seeking it.

—*Ralph T. Knight, M.D.*
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Book Reviews

Pain. Research Publications, Association for Research in Nervous and Mental Disease, Vol. XXIII. Editorial Board: Harold G. Wolff, M.D., Herbert S. Gasser, M.D., and Joseph C. Hinsey, Ph.D. Pp. 468, with 116 illustrations, and 19 tables. Baltimore, 1943, Williams & Wilkins Company, \$7.50.

As everyone interested in nervous and mental diseases knows, the Association for Nervous and Mental Diseases holds a meeting annually to discuss some subject in the field of neurology or psychiatry, and the proceedings are published in book form annually. At the twenty-third meeting, held in 1943, the subject of discussion was pain.

Thirty-two chapters, each consisting of an address given at the meeting, make up the contents of this volume; each is by an investigator writing on some phase of pain, and most chapters include also a discussion which followed the reading of the report at the meeting.

Most of this material has been published elsewhere by the participants in the periodic literature, but its compilation here in a single volume makes it an indispensable reference book for libraries and for individuals who have a special interest in investigation of the mechanism of pain, significance of pain in diagnosis, or methods of pain relief.

It is impossible to detail the contents of these thirty-two separate reports, and it would be improper discrimination to choose only a few for special mention; therefore, let it suffice to say that it covers all phases of pain, fundamental researches, clinical manifestations, and methods of relief.

This book is well edited, and the illustrations are very well reproduced.

Technique in Trauma. By Fraser B. Gurd, M.D., C.M., and F. Douglas Ackman, M.D., C.M., The Montreal General Hospital and McGill University. Ed. 3. Pp. 68, with 3 illustrations. Philadelphia, 1944, J. B. Lippincott Company, \$2.

This book consists of a group of three papers entitled: (1) A Practical Concept for the Treatment of Major and Minor Burns, (2) A Report on the Management of Burns, and (3) Planned Timing in the Treatment of Wounds and Infections by Means of Infrequent Occlusive Dressings.

Out of a confusing welter of statements and strangely organized material it seems that the lesson the book strives to convey is that burns and many wounds are well handled by infrequent changes of dressings, a practical application of familiar experimental studies. The presentation of results with the infrequent change of pressure dressings containing a paraffin sulfathiazole emulsion is not too striking and does not impress one as more favorable than other pressure methods now in vogue. Emphatic recommendation of sulfathiazole locally and discouragement of systemic use seem to run counter to the findings of Meleny and his collaborators.

Despite the criticisms which quickly came to mind on reading this volume, it is obvious that the authors are endeavoring to evaluate fairly a method of therapy not employed widely elsewhere, and one which has much to recommend it. It is a thought-provoking little volume, and one which should be familiar to the surgeon or general practitioner whether or not he chooses to follow the techniques outlined.

Penicillin in Warfare. By several authors. Supplement to British Journal of Surgery. Vol. XXXII, No. 125. Baltimore, Md., 1944, Williams & Wilkins Company, \$2.50.

Remarkable advancements have been made during World War II in the management and treatment of the wounded. There is no doubt that the availability of adequate supply of penicillin has contributed greatly to this. Reports concerning the achievement

therapy with penicillin have remained scattered. This supplement presents an excellent summary of the experience of a group of capable individuals, who composed a "penicillin team" in the Mediterranean Theatre during 1943 and 1944. It should prove to be of value, not only to those engaged with the medical problems of war, but equally informative to those in civilian medical practice.

Introductory articles record "The Principles of Medical Treatment" by Flory and Jennings; "Bacteriological Methods in Connexion With Penicillin Treatment" by Garrod and Heatley; and a brief analysis of the "Application of Penicillin to War Wounds" by Jeffrey. Scott Thompson has a helpful review of "The Bacteriological Examination of Wounds Treated With Penicillin." Detailed clinical reports include the prophylactic and therapeutic value of penicillin in soft-tissue wounds and open fractures. Gas gangrene constituted not a negligible problem in Italy, and the English concluded that penicillin definitely aided surgery and antiserum in lowering the mortality rate. On the other hand, Cutler and Sandusky of the United States Army, reporting on a smaller group of cases of gas gangrene, were unable to ascribe any significant prophylactic or therapeutic benefit to penicillin. Three papers detail a survey of the results of penicillin in war wounds of the chest and in head and spinal wounds. As a part of the problem of medicine in war, results of the use of penicillin in gonorrhea and in syphilis are presented. A bibliography summarizing most of the outstanding reports on penicillin concludes the supplement.

It is apparent that in warfare the judicious and prompt use of penicillin in wounded personnel will prevent infections, control infections, and supplement other measures in the eradication of sepsis. Throughout these reports the major theme is that penicillin is but an adjuvant to sound surgical principles and meticulous operative procedures.

This supplement is enthusiastically recommended to all surgeons. The editors of the *British Journal of Surgery* are to be commended for placing this timely information before the medical profession in this country.

SURGERY

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No. 2

Original Communications

Symposium on Diseases of the Pancreas

RESECTION OF THE DUODENUM AND HEAD OF THE PANCREAS FOR PRIMARY CARCINOMA OF THE HEAD OF THE PANCREAS AND AMPULLA OF VATER

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THE original operation of resection of part of the duodenum and head of the pancreas for carcinoma of the ampulla of Vater, as reported by Whipple and associates¹ was modified a short time later by Brunschwig² to a more radical resection for carcinoma of the head of the pancreas. The technique presented by Brunschwig, which was devised for carcinoma of the head of the pancreas, makes the principle applicable to many more patients since carcinoma is much more frequent in the head of the pancreas than in the ampulla of Vater. With earlier diagnoses and improvements in preoperative treatment of the patient (including the tremendous value of ample transfusions on the operating table) more and more such operations will be performed. The operation is complicated and literally consumes hours for completion; for these reasons numerous modifications of the original operation reported by Whipple and associates have been suggested. Because of the large number already presented, we are apologetic for reporting another, but appreciation of maintenance of certain physiologic principles and efforts to shorten the numerous procedures of the operation have led us (through our very limited experience with five cases of resection) to development of a procedure which will be described in detail later.

An important modification (suggested by Whipple¹ in 1941) of the original operation is the anastomosis of the jejunum to the common duct, instead of to the gall bladder, to prevent the serious effects of infection (suppurative cholangitis) and a "blowout" at the ligated end of the common duct. As a matter of fact, the technique reported by Orr,³ in 1941, on a patient who previously had had a cholecystectomy, utilized a choledochojejunostomy. A one-stage method reported in 1942 by Pearse,⁴ consisting of the implantation of the cut end of the pylorus into the side of the jejunum, was a very simple one but the anastomosis of the jejunum to the gall bladder would appear undesirable.

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In 1941, Whipple¹ and Trimble and associates⁷ independently reported a one-stage operation consisting of antecolic anastomosis of the jejunum to the end of the common duct and the pyloric end of the stomach (see Fig. 1). The anastomosis was made so that the food stream passed upward toward the lesser curvature of the stomach and over the transplanted end of the common duct. Hunt⁶ (1941) performed the operation in one stage, transplanting the cut end of the pancreas into the open end of the distal duodenum or proximal jejunum. In 1942, Orr⁷ reported a one-stage procedure in which he closed the pyloric end of the stomach, did a gastroenterostomy, and transplanted the common duct into

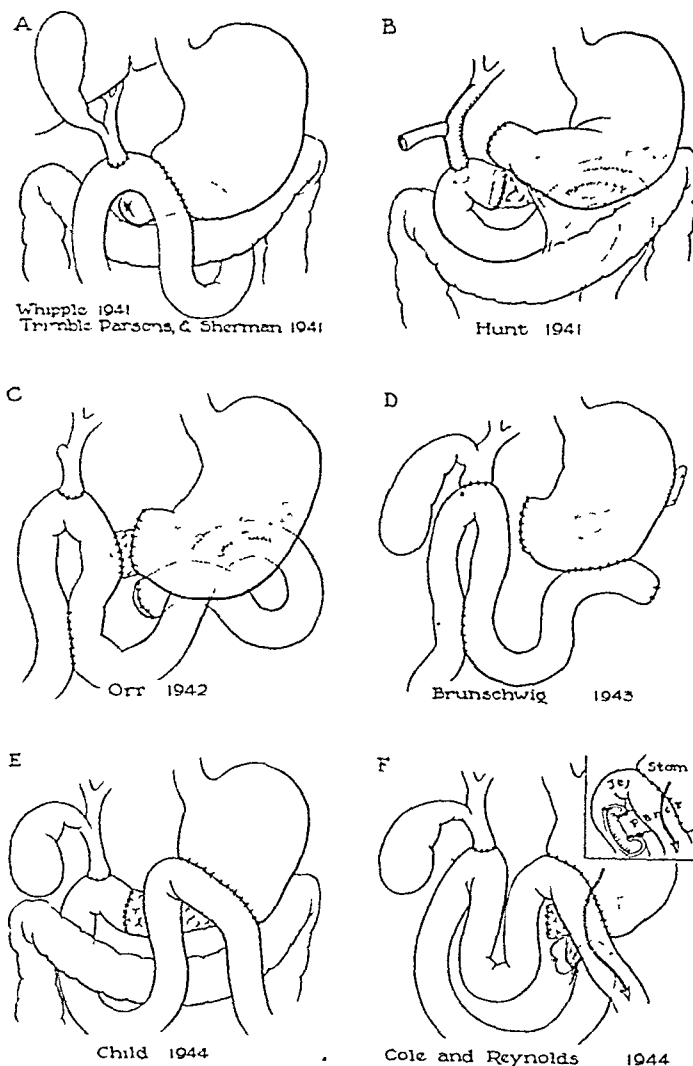


Fig. 1.—Numerous types of one-stage resections for carcinoma of the head of the pancreas or ampulla of Vater have been suggested. Among these are operations described by (A) Whipple and Trimble and associates, (B) Hunt, (C) Orr, (D) Brunschwig, (E) Child, and (F) Cole and Reynolds.

a loop of jejunum (see Fig. 1). The one-stage procedure reported by Brunschwig⁸ (1943) consists of a posterior gastroenterostomy and anastomosis of a loop of jejunum to the common duct with a jejunojejunostomy performed between the two loops of jejunum (see Fig. 1). Along with several other methods, Child⁹ reported a simplified one-stage procedure (1944) in which he implanted the cut end of the pancreas into the open end of the jejunum. The stump of common duct was transplanted into the jejunum proximal to the end-to-side gastrojejunostomy (see Fig. 1). Dennis¹⁰ (1942) reported a one-stage resection

in which he performed a cholecystojejunostomy and a retrocolic Polya gastrojejunostomy. Cattell¹¹ (1944) described a technique in which he performed an end-to-end gastrojejunostomy according to a Billroth technique, transplanted the end of the common duct and cut end of the pancreas into a loop of jejunum.

The recent demonstration of the fact that we can operate for hours even on aged patients, if we resort to meticulous preoperative care and give large quantities of blood during the operation, now justifies performance of resections of the duodenum and head of the pancreas in one stage, with of course a few exceptions. For this reason, and for the sake of brevity, the discussion of the various modifications has been limited to one-stage procedures. If emergency indicates, any of the one-stage procedures can be broken into a two-stage operation of variable types.

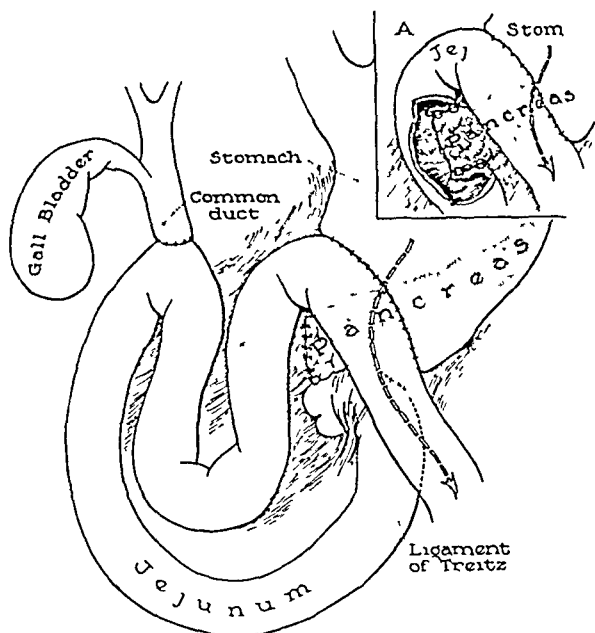


Fig. 2.—Technique of the one-stage resection of duodenum and head of the pancreas adopted by us after trial with several different types. Note that the common duct is transplanted proximal to the gastrojejunostomy so that the food stream will not pass over it but will pass downward (assisted by gravity) instead of upward and over the transplanted duct as in some operations recommended.

Insert shows an alternate procedure of also transplanting the cut end of the pancreas into the jejunum. The proximal loop of jejunum is left long to make room for transplantation of the common duct and, if desired, also the stump of pancreas; however, it need not be so long if transplantation of the stump of the pancreas into the jejunum is not done or contemplated.

TECHNIQUE OF OPERATION

In the five cases herein reported we have utilized several different types of operations. However, the method which we have finally adopted as the procedure of choice is one hitherto unreported and consists of a one-stage resection of the duodenum and head of the pancreas with transplantation of the common duct into the jejunum and performance of an end-to-side gastrojejunostomy (see Fig. 2) so that the food stream will not pass over the transplanted end of the common duct.

A longitudinal midline or modified transverse incision is made in the upper abdomen. After demonstrating that no metastases are present it must be determined whether or not the tumor can be dissected from the superior mesenteric and portal veins. To ascertain this, the peritoneum along the greater curvature of the duodenum is cut and the duodenum with the head of the pancreas lifted

up. We have found dissection easier if begun inferiorly and laterally, but if a line of cleavage is not found with one approach, another should be tried. Perhaps the most important precaution is not to injure the superior mesenteric or portal vein; an accidental tear can be repaired, but such an accident consumes precious time in its repair and for other reasons, including possible thrombosis, should be avoided if at all possible. The common duct is divided as far distally as possible. The gastroduodenal and inferior pancreaticoduodenal arteries are then ligated, but not until the operability of the tumor is definitely established, since ligation of both of these vessels would result in gangrene of the duodenum. The pylorus and distal duodenum at the ligament of Treitz are then divided (see Fig. 2). The distal end of the duodenum or proximal end of the jejunum is turned in with at least two rows of sutures, the outer of which should be cotton or silk. A long loop of jejunum (at least fifteen inches) is then brought up and an end-to-side gastrojejunostomy performed. The chief purpose of the long loop is to have room for transplantation of the stump of pancreas into this loop, if time permits and the procedure seems advisable. The end of the common duct is transplanted into the jejunum, leaving as much distance as possible between the site of transplantation and the gastrojejunostomy so that possible contamination or exposure to food stream can be minimized. In this anastomosis the mucosa of the jejunum should be anastomosed directly to the mucosal surface of the common duct (with interrupted fine catgut), to minimize stenosis, as has been emphasized by Cattell. A second row of interrupted silk or cotton, attaching serosa to serosa, is of course indicated.

The jejunal loop may be brought up either anterior or posterior to the colon depending upon the length of the jejunal mesentery and thickness of the mesocolon. If the jejunal mesentery is short and the jejunum brought up anterior to the colon, anastomosis of this loop of jejunum to the end of the common duct may put tension on the proposed suture line at the site of transplantation of the common duct; if this is the case an opening should be made in the mesocolon and the jejunal loop brought up posterior to the colon. If the edge of the opening in the mesocolon is attached to the walls of the two loops of jejunum by numerous interrupted sutures there need be no fear of development of intestinal obstruction. In Case 1, in which the technique as described and illustrated in Fig. 2 was followed, the jejunum was brought up anterior to the colon.

We have not been transplanting the cut end of the pancreas into the intestine largely because, to date, very little ill effect has been observed by the various authors reporting on this subject, following complete closure of the pancreatic stump. This problem will be discussed in greater detail later.

During closure of the wound it is advisable to insert a drain down to the stump of the pancreas, largely because a pancreatic fistula develops so commonly in spite of efforts to ligate the pancreatic duct, and close the stump of the pancreas with nonabsorbable sutures.

DISCUSSION OF OPERATIVE PRINCIPLES

In addition to efforts to shorten the operative procedure one must endeavor to restore anatomic structures in such a way that normal physiology will not be disturbed.

Unless the tumor has invaded the duodenum so far distally as to impinge upon the ligament of Treitz, we believe it is timesaving to transect the duodenum proximal to the ligament of Treitz and turn it in, rather than to cut the ligament itself and dissect the bowel from the mesenteric vessels. Invagination of a

stump of bowel the size of the duodenum can be done so rapidly and safely that it will not be time-consuming. It appears to us that anastomosis of the cut end of the stomach to the loop of the jejunum requires much less work than closure of the stomach and performance of a gastroenterostomy of the usual posterior type. In our experience, it makes no difference whether the jejunum is brought up anterior or posterior to the colon. The deciding factor should be the length of the mesentery of the jejunum, and the length, vascularity, and thickness of the mesocolon. If the mesocolon is short and thick, or marred with a great many vessels, it would certainly be desirable to bring the jejunum up anteriorly if the mesentery will allow it to reach the end of the common duct without tension. The anterior position is desirable from the standpoint of consumption of time, since it will naturally take several minutes to anchor the edge of the opening in the mesocolon to the two loops of jejunum after they are brought up posterior to the colon.

As yet there is no agreement as to whether or not the stump of the pancreas should be closed tightly or be transplanted into the stomach or jejunum. Brunschwig⁸ and others have expressed the opinion that so little ill effect is sustained by closure of the pancreas that indications for transplantation are insufficient to warrant the time required. The amount of unabsorbed fat in the feces after operation, as reported by various authors (Whipple,¹ Dennis,¹⁰ Brunschwig and Allen¹²), varies tremendously. The latter authors report the wide variation of 91.2, 96, and 8.4 per cent in three cases studied; in the first of these cases the unabsorbed fat dropped from 91.2 to 65 per cent under pancreatin therapy. It is true that practically all of these pancreatic fistulas will close spontaneously after several weeks, and that rarely are any nutritional disturbances encountered. However, we do have one patient who has had a fistula for seven months and who developed a diarrhea with profound weakness for several weeks after operation. He improved under strict dietetic care and pancreatin, but still has a pancreatic fistula and is not gaining weight. One other important point in a discussion about transplantation of the stump of the pancreas into the intestine is a question as to whether or not the pancreatic duct will remain open. At the present time we have no information to answer this question. It would naturally not be desirable to take the time to transplant the stump of the pancreas if the duct were going to close within a short time after transplantation. However, we do know that the duct remains open for several weeks. Transplantation might, therefore, improve the immediate convalescence. We predict that as time goes on there will be a tendency to transplant the stump of the pancreas, at least on some occasions. Poth¹³ recommends transplantation of the pancreatic duct into the jejunum and reports the use of a small silver tube to maintain patency of the duct.

We are convinced of the desirability of hooking up the jejunum in such a way that the food stream will not flow over the site of transplantation of the common duct into the jejunum. We believe that infection of the cholangitis type will be minimized if the food stream does not flow over the transplanted common duct. It is true that suppurative cholangitis in these operations is not very common, but it is being observed by many surgeons performing the operation. For example, Whipple¹ stated that he had abandoned the cholecystojejunostomy because of a possible "blowout" of the common duct or infection with development of cholangitis. Child⁹ stated that "although the gall bladder was utilized in Cases 2, 3, 4, and 5 without the development of any immediate postoperative complications, troublesome attacks of acute cholangitis marred the

result in Case 4." In a resection of the stomach and head of the pancreas, performed by one of us, not herein reported because the tumor was primary in the stomach, death was caused primarily by a suppurative cholangitis; the common duct had been tied and the gall bladder anastomosed to the jejunum. If suppurative cholangitis occurs in no more than 5 or 10 per cent of cases it would appear worth while to attempt to modify the procedure in such a way as to avoid this complication. As a matter of fact, we have encountered suppurative cholangitis in several of our patients upon whom we performed a plastic operation upon the common duct for benign stricture, but true enough it usually occurred in those cases in which a vitallium tube was used at the anastomotic line between the common duct and jejunum; on two occasions we were able to prove that the food or secretions entering the biliary system were the cause of the cholangitis because the chills and fever stopped abruptly when we interrupted the loop of jejunum which had allowed reflux of food into the intra-hepatic ducts through the vitallium tube.* Although there is no concrete evidence that hooking up the loop of intestine with the common duct distal to the gastric stoma would result in less cholangitis than when it is hooked up proximal to the gastric stoma, it appears worth while to resort to the latter plan since the amount of operative work is the same. Perhaps a more prominent reason for rotating the jejunum so that the food stream will pass downward as in Fig. 1*F*, rather than upward as in Fig. 1*A*, is the fact that in the former instance the food can empty from the stomach into the intestine by *gravity* and will not have to be forced *upward* to make the turn into the jejunum.

ABSTRACT OF CASE REPORTS

CASE 1.—Patient G. S., a Negro woman, aged 49 years, entered the Illinois Research Hospital, April 3, 1944, complaining of jaundice. The onset was three years before, with development of painless jaundice accompanied by severe itching. Stools were clay-colored. After three months, symptoms cleared and she was relatively asymptomatic. A second attack developed one year before admission and, like the first, consisted of onset of painless jaundice with itching. In August, 1943, laparotomy was performed elsewhere, and a large distended gall bladder removed. Bile drained from the wound for two months. After the biliary fistula closed, jaundice and itching again developed.

Physical Examination.—The patient was intensely jaundiced; there were numerous scratch marks on the skin. No masses were felt in the abdomen except for the liver edge which was felt about two fingerbreadths below the costal margin. The rest of the examination was relatively negative.

Laboratory Examination.—Red blood cells, 2.8 million; hemoglobin, 6.5 Gm.; white blood cells, 11,700. Urine was negative except for large quantities of bile. The serum albumin was 3.0 and serum globulin 2.5 Gm. per cent. Blood chlorides and nonprotein nitrogen were normal. Icterus index was 53; blood amylase 326 (normal 80 to 150). Stool was acholic.

After numerous transfusions, laparotomy was performed, May 1, 1944. Numerous adhesions were present; a small stump of the gall bladder remained. In the duodenum at the site of the ampulla of Vater was an irregular, indurated mass about 3 by 5 cm. This appeared definitely to be carcinoma, and presumably was arising from the head of the pancreas or ampulla of Vater, probably the latter. No metastases were present. We, therefore, decided upon a resection. The duodenum and head of the pancreas were removed according to the technique previously described in this report. The distal end of the duodenum was turned in with a double row of catgut sutures, the upper end being cut at the pylorus. The loop of jejunum was brought up anterior to the colon for anastomosis with the common duct and stomach. The cut end of the pancreas was closed with interrupted cotton sutures. An end-to-side anastomosis was done between the end of the stomach and the jejunum (see

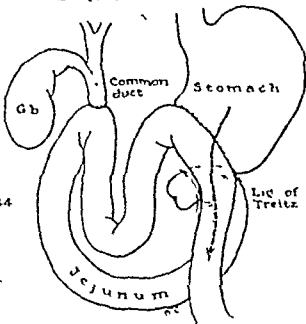
*These patients will be discussed in detail in another publication dealing with plastic operations on the common duct, utilizing vitallium tubes.

Fig. 2). The common duct was transplanted into the jejunum proximal to the gastric anastomosis so that food would not flow over the opening of the transplanted common duct.

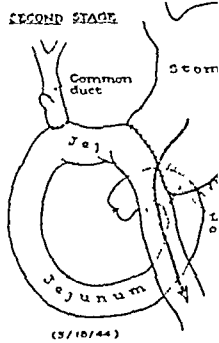
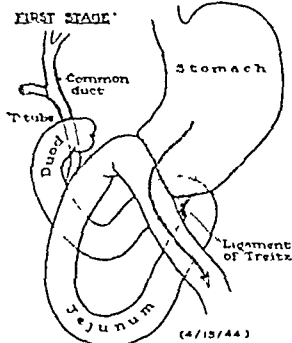
Microscopic diagnosis was papillary adeno- and gelatinous carcinoma of the ampulla of Vater involving the duodenal wall and head of the pancreas. Convalescence was unusually smooth and the patient left the hospital on the sixteenth postoperative day. When last seen, six months after operation, she had recovered except that she still felt a bit weak and was still twenty-five pounds under her pre-illness weight. The pancreatic fistula drained for four months but caused very little irritation of the skin.

CASE I
Carcinoma of the Ampulla of Vater

49 year old colored female. Painless, intermittent jaundice of 3 years duration. Cholecystectomy 8 mos. previously. Fistula closed, then itching and jaundice returned. One stage operation 5/1/44. CONVALESCENCE Smooth. Pancreatic fistula closed at 4 months. Still 25 lbs. underweight, no diarrhea.

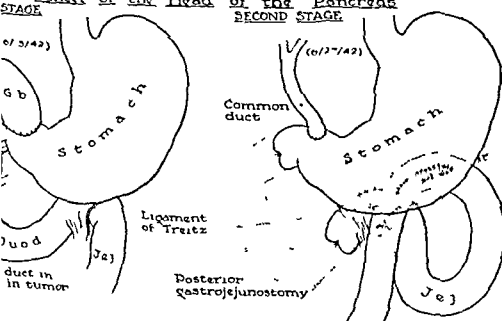


CASE II
Carcinoma of the Head of the Pancreas



59 year old white male. Abdominal pain, chills and fever 3 weeks before his entrance. Cholangiochostomy imperative because cholangitis. Therefore 2 stage operation necessary. CONVALESCENCE Slow. Pancreatic fistula still open after 7 months. Nutritional disturbance. Protein loss with ankle edema, diarrhea. Weight loss. Albumin 3.3, Globulin 2.2. Marked improvement on high protein diet.

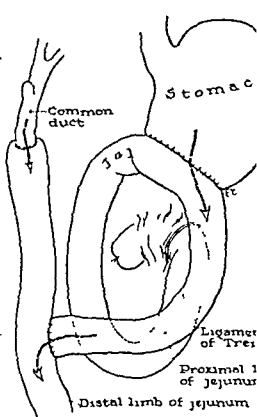
CASE III
Cancer of the Head of the Pancreas



67 year old white male. Abdominal pain for 2 months. X ray showed deformity. Jaundice 10 days prior to entry. Cholangiochostomy failure because cystic duct penetrated in pancreas. Death on 9th postoperative day following 2nd stage. Cause of death: peritonitis.

Cancer of the Head of the Pancreas
CASE IV

54 year old white male. Weight loss of 25 pounds in last 2 months. Jaundice and itching 1 month. One stage operation 9/8/42. CONVALESCENCE Good. Biliary drainage for 3 weeks. Uroepsis. Intestinal obstruction at 9 months. No metastases found at operation. Complete recovery, now at work.



CASE V
58 year old white male. Weakness and weight loss of 45 pounds in 15 months. Cholangiochostomy followed by chills and fever. Improvement with a tube in cholangiochostomy. drank bile daily. Gained 12 pounds. One stage operation 7/12/44. CONVALESCENCE Rapid. Paroxysmal parietal tachycardia 48 hours postoperatively. Hony 2 on 9th postoperative day. Dietary difficulty. Ankle edema, diarrhea, low blood proteins. Improved on high protein diet.

Fig. 3.—Summary of our own five cases of pancreaticoduodenectomy, illustrating the types of operation in each patient. The method illustrated in Case 1 is the one preferred by us.

CASE 2.—Patient E. K. was a white man, 59 years old, who entered the Illinois Research Hospital, April 6, 1944, complaining of pain in the abdomen, chills, fever, and jaundice of three weeks' duration. Pain was greatest just to the left of the umbilicus and radiated throughout the abdomen. There was a history of epilepsy of several years' duration.

Physical Examination.—The patient was emaciated and deeply jaundiced. The temperature was 102° F. The abdomen was quite tender to palpation throughout, particularly in the right upper quadrant where the liver was felt to be enlarged about 6 cm. beyond the costal margin.

Laboratory Examination.—Red blood cells, 4.7 million; white blood cells, 9,500; blood chlorides, nonprotein nitrogen, and blood proteins were normal. The icterus index was 82.

The patient continued to have a septic type of fever indicating that a suppurative cholangitis was present. Accordingly, April 15, 1944, a laparotomy was performed. A

choledochostomy was done and purulent material was obtained from the common duct. The head of the pancreas was enlarged and very hard; the diagnosis of carcinoma seemed obvious. No metastases were present and the tumor appeared operable. The patient was obviously too ill for a one-stage operation to be considered. However, an end-to-side posterior gastrojejunostomy was performed in addition to the choledochostomy. The cut end of the duodenum was closed with two layers of sutures. The patient recovered slowly, although the fever subsided rapidly following drainage of the common duct.

May 18, 1944, the *second operation* was performed. The head of the pancreas and duodenum were resected, turning in the distal duodenum. The cut end of the pancreas was closed with interrupted cotton sutures. The common duct was transplanted into the jejunum proximal to the gastrojejunostomy. He was discharged four weeks after the second operation but a few weeks later developed a diarrhea which resulted in extreme weakness and an additional weight loss of three or four pounds. In addition, he developed considerable ankle edema. The serum albumin was 3.3 and serum globulin 2.2 Gm. per cent. There was likewise still profuse drainage from the pancreatic fistula. He was readmitted on the medical service and given choline, pancreatin, and a high protein diet. The diarrhea and edema of the extremities disappeared within one week. At the present time, seven months after his second operation, the pancreatic fistula is still draining several hundred cubic centimeters per day. A third laparotomy is contemplated to transplant the stump of the pancreas into the jejunum.

CASE 3.—Patient R. S. J. (Hospital No. 21738), a white man, aged 69 years, entered St. Luke's Hospital, June 1, 1942, complaining of severe constant epigastric pain for the previous two months. Pain was constant (not colicky), and unrelated to food intake. It interfered with his sleep and did not radiate. He had lost thirty pounds during the last two months. Urine had been dark and stools white only during the past week. Icterus was present only for two days preceding admission. The physician who originally saw the patient noticed a filling defect in the stomach which he thought to be carcinoma. The patient postponed surgery because he was working and felt he needed the money.

Physical Examination.—Temperature, pulse, and respirations were normal. Blood pressure was 150/64. No masses were felt in the abdomen, although an indefinite sense of resistance was noted in the right upper quadrant. A diagnosis of carcinoma of the head of the pancreas or carcinoma of the stomach with metastases was made.

Laboratory Examination.—The Kahn test was negative. Urine was normal except for bile. Icterus index was 15; serum protein 7.06 grams per cent; blood chlorides 640; non-protein nitrogen, 40; red blood cells, 5.1 million. No bile was found in the stool but the benzdine test was slightly positive.

June 13, 1942, *laparotomy* was performed. A carcinomatous mass was found in the head of the pancreas and considered operable. *Cholecystogastrostomy* was done as a first stage operation.

June 22, icterus index was 40. June 29, glucose tolerance test was normal. Stool showed a large amount of fat. June 30, there was no benefit shown from cholecystogastrostomy; jaundice was deepening.

June 27, 1942, the *second operation* was done. Pancreaticoduodenectomy and posterior side-to-side gastrojejunostomy were performed. The gall bladder was removed because the cystic duct was blocked by the tumor of the pancreas. (This explained the lack of benefit from cholecystogastrostomy.) The common duct was implanted into the stomach. Obstructive biliary cirrhosis of the liver was also present.

July 2, 1942, red blood cells, 4.6 million; hemoglobin, 13. July 3, amylase, 0; blood chlorides, 615; carbon dioxide, 61.4 volumes per cent. The patient did well until July 6, when a sudden turn for the worse occurred. He died on July 9; clinically "hepatic insufficiency" appeared to be an important factor in his downward progress.

Autopsy revealed generalized acute serofibrinous peritonitis; a localized abscess and hemorrhage were noted in the fibrinous adhesions in the region of the ligamentum hepatoduodenale. The impression at the time was that the peritonitis was not in itself enough to be fatal. The sutures in the superior mesenteric vein had produced no thrombus.

Microscopic examination of the specimen removed July 1, 1942, revealed a primary carcinoma of the head of the pancreas.

CASE 4.—Patient J. B. (Hospital No. 43-37636), a white man, entered Cook County Hospital, Aug. 13, 1943. Aside from large veins and swelling of the legs, the history was

negative until about two months before, when he began to note that he had been losing some weight. One month before admission jaundice began to appear. In the previous two months he had lost twenty-five pounds. Itching had been associated with jaundice.

Physical Examination.—The temperature was 98.6° F.; pulse, 80; respirations, 22; blood pressure, 106/58. The skin was lemon yellow in color. Slight nasal deformity was present. The chest was kyphotic and emphysematous. The liver margin was down at least 7 cm. Bilateral pitting edema of the lower extremities was present. Rectal examination revealed clay-colored feces. A diagnosis of carcinoma of the pancreas was made.

Laboratory Examination.—Bile was present in the urine to a 4 plus degree, but no albumin. Blood: red blood cells, 3.8 million; hemoglobin, 70. X-ray: no apparent pathologic findings were noted in the stomach or duodenum. Aug. 16, 1943, nonprotein nitrogen, 35; creatinine, 1.7; serum albumin, 3.6; serum globulin, 2.4; Takata-Ara, 1 plus.

Aug. 27, 1943, blood cholesterol, 552; esters, 222. Sept. 3, blood amylase, 16 (normal 80 to 150). Sept. 4, nonprotein nitrogen, 27; serum albumin, 3.4; serum globulin, 2.5; red blood cells, 4.3 million; hemoglobin, 80.

Laparotomy.—Sept. 8, 1943, one-stage resection of the head of the pancreas was performed. The tumor was small. A few lymph nodes were present but they did not appear to be carcinomatous. (Biopsy of the pancreas at that time was positive for carcinoma.) A resection of the stomach (posterior polya technique), duodenum, and pancreas was performed along with a cholecystectomy. The common duct was anastomosed to the jejunum utilizing the Roux principle.

Sept. 9, 1943, the patient developed massive atelectasis which was relieved by hyper-ventilation and cough. Sept. 25, icterus index, 37. Considerable biliary drainage noted. Oct. 3, chill; urinary tract infection. Oct. 5, cystoscopy. The patient had severe generalized cystitis with a contracture of the vesical neck and three ounces of residual urine. There was no upper urinary tract instrumentation.

Oct. 20, bile drainage had ceased. Stools showed bile and a moderate amount of undigested fat. The odor was very foul. Nonprotein nitrogen, 23; serum albumin, 3.4; serum globulin, 1.7. Oct. 22, the patient was discharged. At no time did he have a pancreatic fistula.

Nov. 23, 1944, patient has been seen repeatedly since. He had a small suprahepatic abscess drained about nine months after the original operation. At that time no metastases were seen. He is now working and is apparently well.

CASE 5.—Patient C. S. (Hospital No. 55167), a white man, aged 58 years, was admitted to St. Luke's Hospital, July 1, 1944. His health was good until fifteen months before, at which time he noted progressive weakness with no apparent cause. He was treated until January, 1944, without relief. He had lost forty-five pounds in the nine-month interval.

In February he had a gall bladder visualization at another hospital and a pathologic gall bladder was found; February 24, the gall bladder was drained and a single gallstone removed. Since that time he has had a draining incision; especially profuse after meals. (Jaundice and itching appeared in January.) After the gall bladder drainage, the jaundice and itching disappeared. He has had occasional chills and fever since.

Physical Examination.—The patient was a poorly nourished white man with a slight yellow tint to the skin. The abdomen revealed a sinus from which bile oozed. The blood pressure was 118/74. He had a chill on the day of entrance. Shortly thereafter a catheter was introduced into the gall bladder sinus and better drainage established. No more chills occurred.

Laboratory Examination.—Red blood cells, 5.3 million; hemoglobin, 15.1 Gm.; white blood cells, 9.9; Kahn, negative; nonprotein nitrogen, 25.2; blood chlorides, 575 phosphorus, 3.67; vitamin C, 0.6; phosphatase, 9.63; icterus index, 15; prothrombin time, 35 seconds; serum albumin, 3.5; serum globulin, 2.02; hematocrit, 43; urine, negative.

The patient was given a high protein diet with vitamin K and he drank bile daily. He gained ten pounds in the twelve days between entrance and operation.

Operation.—July 12, 1944, one-stage resection of the duodenum and head of the pancreas was performed. A Polya anastomosis and choledochojejunostomy of the Roux type were performed, both retrocolic. The patient was given 2,000 c.c. of blood while on the operating table. Three holes were accidentally made in the superior mesenteric vein, which required considerable time for repair.

July 14, 1944, the postoperative course was uneventful except for development of auricular flutter (?). The pulse rose to 180 but responded well to six doses of quinidine (gr. 3).

July 21, the patient left the hospital, nine days after the operation.

ANALYSIS OF CASES

Of the five cases herein reported, all the patients had primary carcinoma of the head of the pancreas except one (Case 1), who had a primary carcinoma of the ampulla of Vater with invasion of the duodenum. Two two-stage resections were performed and three one-stage resections. The decision to perform a two-stage operation was mandatory in one patient because of a severe suppurative cholangitis which was present on admission. In two patients a one-stage operation with performance of an end-to-side gastrojejunostomy (posterior Polya technique) with a choledochojejunostomy after the Roux principle as recommended by Whipple¹⁴ in 1938 was performed (see Fig. 1). Although these two patients are alive and doing well fourteen and four months, respectively, since operation, we prefer the technique performed in Case 1 (see Fig. 2) largely because it requires less operative work.

As noted in Fig. 3, a pancreatic fistula developed in two of the five patients. In one of these, seven months after operation the fistula is still draining. The diarrhea and edema of the ankles which developed five to six weeks after operation have disappeared; an operation to transplant the stump of the pancreas into the jejunum is now contemplated. In this patient there has been considerable pain in the region of the fistula, particularly during short intervals when the fistula was closed or draining only a small amount of pancreatic secretion.

Of the five cases herein presented, one patient died; this constitutes a mortality rate of 20 per cent. An insufficient length of time has elapsed since operation to determine the prospects of a five- or ten-year cure.

SUMMARY

A new operation for resection of the duodenum and head of the pancreas for carcinoma is described. In this procedure a long loop end-to-side anastomosis is made between the stomach and the jejunum distal to the choledochojejunostomy. This secures drainage of the biliary tract proximal to the gastric anastomosis and so avoids the danger attendant upon passage of food over the common duct opening. However, the chief advantage of the technique recommended lies in the requirement of less time for performance of the operation; in our estimation suture lines and anastomoses for resection of the duodenum and head of the pancreas are reduced to a minimum. The jejunum is anastomosed to the cut end of the stomach with the distal end to the greater curvature so that the food passes downward by gravity into the jejunum instead of upward into the jejunum as it must in many operations previously recommended.

The chief purpose of the long loop proximal to the end-to-side gastrojejunostomy is to allow transplantation of the common duct and, if desired, the stump of the pancreas, into the jejunum proximal to the gastric anastomosis. Although to date very few surgeons are transplanting the stump of the pancreas into the intestine, we believe this procedure will in the future be performed more often than it is now. In one of our patients, the pancreatic fistula which followed the resection is still draining seven months after operation although now only a few ounces per day.

Four patients with carcinoma of the head of the pancreas and one with carcinoma of the ampulla of Vater have been subjected to radical resection of the duodenum and head of the pancreas. There has been one fatality.*

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*Since submission of this article for publication a sixth resection has been performed, utilizing the preferred procedure as illustrated in Fig. 2; the stump of pancreas was transplanted into the loop of jejunum. Postoperative convalescence was uneventful but since only six weeks have passed, insufficient time has elapsed to determine ultimate results.

PANCREATICODUODENECTOMY FOR CARCINOMA OF THE AMPULLA AND AMPULLARY REGION

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NINE years have passed since Whipple, Parsons, and Mullins⁴⁴ reported their cases of successful resection of the head of the pancreas and duodenum for carcinoma of the ampulla. During these nine years many surgeons have interested themselves in the treatment of carcinoma arising in the ampulla and ampullary region, and many modifications of the technique suggested by Whipple and his associates have been described. The fear that existed for many years, that surgical attack upon the pancreas containing a carcinoma was too great, no longer exists as manifested by the number of operations done since 1935. Whipple⁴⁸ recorded sixty-four cases of radical pancreaticoduodenectomy which he had collected from published records and from personal reports up to April 1, 1942. Since then thirty-five cases have been found recorded in the surgical literature (Table I). Five cases are added in this report making a total of 104. There are undoubtedly many unrecorded cases, but to avoid confusion in a study of the results of the operation, no effort has been made to collect such cases.

Pancreaticoduodenectomy for carcinoma of the ampulla and ampullary area will be discussed under the following headings:

1. Diagnosis at operation
2. Is radical pancreaticoduodenectomy justifiable?
3. Is restoration of the external pancreatic secretion advisable?
4. Choice of one-stage or two-stage operation
5. Choice of technique of pancreaticoduodenectomy
6. Comments upon personal cases

DIAGNOSIS AT OPERATION

Some difficulty may be experienced in making a diagnosis of carcinoma in the ampullary region when the operative field is exposed. Chronic pancreatitis or a benign adenoma may so closely simulate carcinoma that a diagnosis made by palpation alone may lead to a needlessly serious operation. The importance of this statement is clearly emphasized by the case of benign tumor of the ampulla reported by Horsley¹⁸ and the case of chronic pancreatitis recorded in Table II; both patients were subjected to pancreaticoduodenectomy. It is also true that a diagnosis of carcinoma may be made, considered incurable, and proved to be wrong by many years of subsequent good health as shown by Kiefer and Moravec.²² A stone impacted at the ampulla may be mistaken for carcinoma. If in doubt, a correct diagnosis of stone can easily be made by duodenotomy.

A thorough exploration of the liver, head of the pancreas, and regional lymph nodes should be made. In selected doubtful cases a duodenotomy and biopsy of the papillary area may be indicated or a biopsy of lymph nodes or pancreas may be advisable. If the diagnosis is not clear after a biopsy of the

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papilla, lymph nodes, or head of the pancreas, it is wise to plan the operation in two stages and complete the second stage after a positive diagnosis of an operable carcinoma is made. If gross or microscopic evidence of carcinoma is found in the regional lymph nodes or liver, the second stage of the operation should be abandoned. It is doubtful if life can be prolonged by a palliative pancreaticoduodenectomy when proved metastases are present.

IS RADICAL PANCREATICODUODENECTOMY JUSTIFIABLE?

In a discussion of a paper by Harvey and Oughterson,¹⁷ in 1942, Whipple⁴⁸ stated that radical operation for carcinoma of the ampullary region "is still unquestionably in the experimental stage."

It is generally believed that carcinomas arising in the papilla of Vater or ampulla grow slowly and metastasize late. Baggenstoss¹ supported this belief in his report that fifteen of twenty-eight carcinomas of the papilla of Vater did not show metastases at necropsy. If this assumption is true, a high percentage should be curable by radical operation. Considering the number of patients who have survived the radical operation and later died of metastases, the belief that the growth of the carcinoma is local for a very long period of time becomes less impressive. Five of the eight patients on whom I did pancreaticoduodenectomy died of metastases. Although the results of the cases reported from April 1, 1942, to Nov. 1, 1944, are incomplete, metastases were present at death, at operation, or were noted before death in six of twenty cases with follow-up records.

There has been no accurate publication of the final results of pancreaticoduodenectomy. Until a careful study is made, it will be difficult to state with any degree of accuracy what percentage of cures may result or what the average length of life will be following this operation. It is also difficult at present to compare and draw conclusions from the results obtained by the palliative operation, the transduodenal resection, and the radical operation (Tables III, IV, and V). The data available are not very convincing that pancreaticoduodenectomy is superior to less radical measures. Regardless of our lack of knowledge of final results, radical excision of a carcinoma arising in the ampullary region by the Whipple type of operation fulfills the requirements of cancer surgery in general and offers the greatest hope for the greatest number of cures in the future.

IS RESTORATION OF THE EXTERNAL PANCREATIC SECRETION DESIRABLE?

In 1908, Sauv  ³⁸ stated that from the physiologic standpoint the head of the pancreas may be resected without anastomosis of the duct of Wirsung to the intestines. Berg and Zucker³ described fatty degeneration of the liver in experimental animals after ligation of the pancreatic ducts. It is reasonable to expect that fat digestion would be disturbed by excluding the external pancreatic secretion, but Whipple, Parsons, and Mullins,⁴⁴ in their first cases of radical pancreaticoduodenectomy, found that 80 to 90 per cent of the fat was absorbed. They suggested that there might be a compensatory secretion of a fat-splitting ferment in the upper intestine. According to Montgomery,²⁶ experimental ligation of the pancreatic ducts results in atrophy of the pancreatic acinar structures and fatty infiltration of the liver. He warned that obstruction of the secretory mechanism of the pancreas in patients will lead to major disturbances of the individual's ability to control his lipid metabolism, which must be controlled by replacement therapy. Cole and Howe¹¹ recognized the relationship between disease of the pancreas and fatty infiltration of the liver.

TABLE I. LIST OF COLLECTED CASES FROM APRIL 1, 1942 (DATE OF WHIPPLE'S REPORT) TO NOV. 1, 1944

AUTHOR	DATE REPORTED	AGE	SEX	TYPE OF OPERATION	RESULT
					In good health after 2½ yr.
Zinninger ¹⁹	June, 1942	62	M	Two-stage: First stage: End-to-side jejunojejunostomy and cholecystojejunostomy Second stage: Posterior gastroenterostomy, pancreaticoduodenectomy and closure of stump of pancreas; seventeen mo. later pancreatic duct and bowel united with vitallium tube	
Orr ²⁸	June, 1942	65	F	Two-stage: First stage: Cholecystogastrostomy Second stage: Posterior gastroenterostomy, pancreaticoduodenectomy, pancreaticojejunostomy and jejunojejunostomy	Alive 3 mo. after operation
Orr	June, 1942	56	F	One-stage: Posterior gastroenterostomy, pancreaticoduodenectomy; choledochojejunostomy, pancreaticojejunostomy and jejunojejunostomy	Alive 3 mo. after operation
Gordon-Taylor ¹⁸	Aug., 1942	60	M	One-stage: Cholecystogastrostomy, posterior gastroenterostomy, pancreaticoduodenectomy, and closure of stump of pancreas	Death 5 days after operation; anuria
Gordon-Taylor	Aug., 1942	58	M	Two-stage: First stage: Jejunum sectioned, end-to-side jejunojejunostomy and cholecystojejunostomy Second stage: Posterior gastroenterostomy, pancreaticoduodenectomy, and closure of stump of pancreas	Death in 6 mo.; hepatic metastases
Gordon-Taylor	Aug., 1942	60	F	Two-stage: First stage: Cholecystogastrostomy Second stage: Posterior gastroenterostomy, pancreaticoduodenectomy, and closure of stump of pancreas	Alive and well 21 mo. after operation
Dennis ¹³	Aug., 1942	64	M	One-stage: Pancreaticoduodenectomy, hemigastrostomy, closure of stump of pancreas, Polya type of gastrojejunostomy, and cholecystojejunostomy	Alive with recurrence after 6½ mo.
Dennis	Aug., 1942	67	M	One-stage: Pancreaticoduodenectomy, hemigastrostomy, closure of stump of pancreas; Polya type of gastrojejunostomy and choledochojejunostomy	Postoperative death; autopsy, metastases not mentioned

Pearson	Sept., 1942	56	F	One-stage: Pancreaticoduodenectomy, cholecystojejunostomy, end-to-side gastrojejunostomy, and closure of stump of pancreas	Left hospital on 58th post-operative day; no later report (proved to be primary carcinoma of duodenum)
Lake, Cornell, and Harrison ²⁴	Jan., 1943	25	F	Two-stage: First stage: Cholecystojejunostomy, section of jejunum, and end-to-side jejunojejunostomy; biopsy Second stage: Posterior gastroenterostomy, partial gastrectomy, and pancreaticoduodenectomy	Alive 1 yr. after operation; recurrence probable, metastases found in lymph nodes at operation
Phillips ³³	April, 1943	44	M	Two-stage: First stage: Exploration of common duct, duodenotomy, cauterization and biopsy of tumor, choledochogastrostomy, anterior gastroenterostomy, and jejunojejunostomy. Second stage: Pancreaticoduodenectomy, ligation of pancreatic duct, and closure of stump of pancreas	Recovered from operation; no later report
Sternfeld and Melley ³⁹	May, 1943	56	M	Two-stage: First stage: Cholecystoduodenostomy Second stage: Detached cholecystoduodenostomy, pancreaticoduodenectomy, closure of stump of pancreas, anterior gastroenterostomy, and cholecystojejunostomy	Died four weeks after second stage of operation
Cattell ⁸	June, 1943	?	?	One-stage: Pancreaticoduodenectomy including pyloric end of stomach, four divisions of duodenum and small proximal portion of jejunum, end-to-end gastrojejunostomy, end-to-side pancreaticojejunostomy, end-to-side choledochojejunostomy over a tube, and jejunojejunostomy	Survived operation
Cattell	June, 1943	?	?		Survived operation
Cattell	June, 1943	?	?		Survived operation
Cattell	June, 1943	?	?	Two-stage: First stage: Antecolic cholecystojejunostomy Second stage: Pancreaticoduodenectomy, antecolic gastrojejunostomy, pancreaticojejunostomy, and jejunojejunostomy	Survived operation
Cattell	June, 1943	?	?	Type and details of operation not recorded	Death on 17th postoperative day

TABLE I.—CONT'D

AUTHOR	DATE REPORTED	AGE	SEX	TYPE OF OPERATION	RESULT
Rekers, Paek, and Rhoads ³⁰	Aug., 1943	39	F	Two-stage: First stage: Cholecystogastrostomy Second stage: Posterior gastroenterostomy, closure of stump of pancreas	Alive 1 yr. after operation
Dragstedt, Julian, Allen, and Owens ¹⁴	Aug., 1943	67	M	One-stage: Cholecystectomy, pancreaticoduodenectomy, closure of stump of pancreas, end-to-end gastroduodenostomy, and hepaticogastrostomy	Died 4 mo. after operation
Gray and Sharpe ¹⁶	Dec., 1943	58	?	Two-stage: Modified Whipple technique; no details of operation	Died of peritonitis 8 days after second stage
Brunschwig ⁵	Dec., 1943	58	?		Death on 4th postoperative day
Brunschwig	Dec., 1943	71	?		Death on 3rd postoperative day
Brunschwig	Dec., 1943	57	?		Died 5 mo. and 3 weeks after operation
Brunschwig	Dec., 1943	46	?	One-stage:	Alive 6 mo. after operation
Brunschwig	Dec., 1943	54	?	Pancreaticoduodenectomy with resection of stomach through antrum and 3 to 6 cm. of jejunum, posterior gastrojejunostomy, choledochojejunostomy, jejunojejunostomy, and closure of stump of pancreas	Death on 8th postoperative day; metastases found at operation
Brunschwig	Dec., 1943	35	?		Died 5 mo. after operation; metastases
Brunschwig	Dec., 1943	73	?		Died on 8th postoperative day
Brunschwig	Dec., 1943	55	?		Alive 6 mo. after operation
Watson ⁴¹	Apr., 1944	43	F	Two-stage: First stage: Antecolic cholecystojejunostomy Second stage: Pancreaticoduodenectomy, section of jejunum and end-to-end gastrojejunostomy, and end-to-side jejunojejunostomy	Alive 182 days after operation

Poth ³⁵	May, 1944	72	M	One-stage: Pancreaticoduodenectomy with partial resection of stomach and 18 in. of jejunum, fundus-to-end cholecystojejunostomy, pancreaticojejunostomy (silver cannula in duct), end-to-side gastrojejunostomy	Alive 4 mo. after operation
Child ⁶	June, 1944	56	F	Two-stage: First stage: Duodenostomy and biopsy, posterior gastrojejunostomy, cholecystogastrostomy, and ligation of common duct Second stage: Pancreaticoduodenectomy, closure of stump of pancreas, and later jejunostomy for feeding	Died 45 days after second operation
Child	June, 1944	52	M	Two-stage: First stage: Cholecystogastrostomy and posterior gastrojejunostomy Second stage: Pancreaticoduodenectomy and closure of stump of pancreas	Died 8 mo. after operation
Child	June, 1944	57	M	One-stage: Pancreaticoduodenectomy, end-to-end retrocolic pancreaticojejunostomy, antecolic gastrojejunostomy, and antecolic side-to-side cholecystojejunostomy	Exploration of abdomen 15 mo. and 20 days after operation revealed general carcinomatosis (proved to be primary carcinoma of duodenum)
Child	June, 1944	69	M	One-stage: Pancreaticoduodenectomy, cholecystojejunostomy, retrocolic end-to-end pancreaticojejunostomy, retrocolic end-to-side gastrojejunostomy	Alive and well 1 yr. after operation
Child	June, 1944	55	F	One-stage: (Previous local excision of tumor of ampulla through duodenum) Pancreaticoduodenectomy, retrocolic end-to-end pancreaticojejunostomy, retrocolic end-to-side choledochojejunostomy, retrocolic end-to-side gastrojejunostomy and cholecystostomy	Discharged on 21st postoperative day

PATIENT	SEX	AGE	TREATMENT	RESULT
C. T.*	M	47	Two-stage operation: First stage: Choledochogastrostomy and posterior gastroenterostomy Second stage: Pancreaticoduodenectomy and closure of stump of pancreas	Lived 33 mo.; autopsy, metastases
M. B.†	F	67	Two-stage operation: First stage: Cholecystogastrostomy and posterior gastroenterostomy Second stage: Pancreaticoduodenectomy and closure of stump of pancreas	Lived 22½ mo.; metastases, no autopsy
G. P.‡	F	65	Two-stage operation: First stage: Cholecystogastrostomy Second stage: Posterior gastroenterostomy, pancreaticoduodenectomy, section of jejunum and end-to-side jejunojejunostomy, and pancreaticojejunostomy	Lived 15½ mo.; cause of death unknown, no autopsy
A. B.‡	M	59	One-stage operation: Posterior gastroenterostomy, pancreaticoduodenectomy, choledochojejunostomy, pancreaticojejunostomy, and jejunojejunostomy	Lived 33½ mo.; metastases, no autopsy
B. R.§	M	66	One-stage operation: Cholecystogastrostomy, posterior gastroenterostomy, pancreaticoduodenectomy, and pancreaticoduodenostomy	Primary carcinoma of duodenum; lived 17½ mo.; metastases, no autopsy
M. R.	F	61	Two-stage operation: First stage: Cholecystogastrostomy Second stage: Posterior gastroenterostomy, pancreaticoduodenectomy, and pancreaticoduodenostomy	Lived 21 days; autopsy, chronic pancreatitis
A. M.	F	72	Two-stage operation: First stage: Choledochogastrostomy, duodenotomy, and biopsy of papilla Second stage: Posterior gastroenterostomy, pancreaticoduodenectomy, and pancreaticoduodenostomy	Alive 22 mo. Nov. 1, 1944
M. S.	F	56	One-stage operation: Posterior gastroenterostomy, pancreaticoduodenectomy; section of jejunum and end-to-side jejunojejunostomy, cholecystojejunostomy, and pancreaticojejunostomy	Lived 8½ mo.; metastases, no autopsy
I. F.	M	54	One-stage operation: Pancreaticoduodenectomy, end-to-side gastrojejunostomy, pancreaticojejunostomy, choledochojejunostomy, and jejunojejunostomy	Alive 8 mo. Nov. 1, 1944

*Reported in Surg., Gynec. & Obst. 73: 240, 1941; (included in Whipple's review)²⁰†Reported in Ann. Surg. 114: 602, 1941.²¹‡Reported in Ann. Surg. 115: 1087, 1942²²

§Reported in Surg., Gynec. & Obst. (in press.)

TABLE III. RESULTS OF PALLIATIVE BILIARY ENTEROANASTOMOSIS

AUTHORS	NUMBER OF CASES FOLLOWED	AVERAGE LENGTH OF LIFE AFTER OPERATION (MO.)	NUMBER OF PATIENTS OPERATED UPON	OPERATIVE MORTALITY (PER CENT)
Judd and Parker, ²¹ 1928	12	7.7	34	47.0
Coller and Winfield, ¹² 1934	19	7.2	30	26.6
Judd and Hoerner, ²⁰ 1935	94	10.2		
Lahey and MacKinnon, ²³ 1938	15	8.6		
Zollinger and Kevorkian, ⁵⁰ 1939	17	9.0	33	21.2
Sallick and Garlock, ³⁷ 1942	25	6.3	50	48.0
Gray and Sharpe, ¹⁶ 1943	4	15.5	11	63.6

This relationship they called the "pancreaticohepatic syndrome." Beazell, Schmidt, and Ivy² believed that it has been clearly demonstrated that exclusion of pancreatic juice from the intestine results in a decided increase in the quantity of fat, nitrogen, starch, and the total carbohydrate eliminated in the feces. In a study of achylia pancreatica, as a result of chronic pancreatitis, these investigators found that the oral administration of pancreatic enzymes (Pancreatin) is of value in reducing the excess of both fat and nitrogen in the feces. The conclusions of Ivy and his co-workers were not substantiated by Whipple and Bauman,⁴⁷ who reported that normal fat absorption is possible when no pancreatic juice enters the intestine. Metabolic studies of a patient with a pancreaticoduodenectomy for carcinoma with exclusion of the external pancreatic secretion made by Lake, Cornell, and Harrison²⁴ have shown that pancreatic enzyme therapy (Holadin) markedly reduced the loss of protein and fat in the feces but did not materially affect the loss of calcium. Studies similar to those of Lake and his associates were made by Rekers, Pack, and Rhoads.³⁶ These authors concluded that the administration of pancreatin resulted in definite clinical improvement of the patient and definitely decreased the quantity of fat and nitrogen in the feces. They also found that administration of lipocaine was without significant effect. Three patients with pancreaticoduodenectomies were studied by Brunschwig and Allen.⁴ In two of their patients bulky fatty stools developed with a radical reduction in fat absorption. In the third patient fat absorption was normal. They remark that the basis for the variation in fat absorption following exclusion of the pancreatic juice in man remains obscure. The two patients having disturbed absorption came to autopsy five and five and one-half months after operation. In each case the pancreas showed marked fibrosis and atrophy of the acinar tissue. Brunschwig⁷ ligated the pancreatic duct of a monkey and the animal lived four years with no evidence of significant physiologic disturbance during this period. At autopsy the immediate cause of death of the monkey was not apparent. There was complete absence of the pancreatic acinar tissue.

Some doubt has been expressed by Brunschwig as to whether appreciable pancreatic secretion exists after implantation of the pancreatic stump into the

TABLE IV. RESULTS OF LOCAL EXCISION OF TUMOR; TRANSDUODENAL EXCISION, EXCISION OF TUMOR WITH SECTION OF DUODENUM, AND RETRODUODENAL EXCISION

AUTHORS	NUMBER OF CASES FOLLOWED	AVERAGE LENGTH OF LIFE OF PATIENTS DEAD WHEN REPORTED (MO.)	AVERAGE LENGTH OF LIFE OF PATIENTS LIVING WHEN REPORTED	NUMBER OF PATIENTS OPERATED UPON	OPERATIVE MORTALITY (PER CENT)
Hunt ¹⁹	56*	17.4 (24 cases)	32.5 mo. (32 cases)	109	31.1
Gray and Sharpe ¹⁶	5	22.8	0	8	37.5

*Cases of recovery from operation with indicated length of life not included.

TABLE V. RESULTS OF RADICAL PANCREATICODUODENECTOMY

AUTHORS	NUMBER OF CASES FOLLOWED	AVERAGE LENGTH OF LIFE OF PATIENTS DEAD WHEN REPORTED (MO.)	AVERAGE LENGTH OF LIFE OF PATIENTS LIVING WHEN REPORTED (MO.)	NUMBER OF PATIENTS OPERATED UPON	OPERATIVE MORTALITY (PER CENT)
Whipple ⁴⁶ collected cases to April 15, 1941	28	7.7 (11 cases)	9.3 (17 cases)	41	26.8
Orr collected cases from April 1, 1942, to Nov. 1, 1944 (Table I)	20	5.0 (6 cases)	9.9 (14 cases)	35	25.7
Orr reported personal cases April 1, 1940, to Nov. 1, 1944 (Table II)	9	21.7 (6 cases)*	15 (2 cases)	9	11.1

*Four of these cases are included in the collected cases but reported before death of the patient. One case was a primary carcinoma of the duodenum which has been reported elsewhere (Table II).

alimentary tract. The experimental work of Person and Glenn³² clearly indicated that the stump of a severed pancreas can be implanted into the alimentary tract without loss of the external pancreatic secretion, atrophy of the pancreas, or fatty infiltration of the liver. After implanting the stump of the pancreas into the stomach, Person and Glenn proved by chemical analysis that the pancreatic secretion was maintained. In one of Child's⁹ patients pancreatic enzymes were demonstrated in the intestinal tract following pancreaticojejunostomy and in four of such cases there was no evidence of digestive disturbances following operation. Child also stated that in these four cases there was no instance of pancreatic fistula which has been such a troublesome complication when the stump of the pancreas is closed. Dragstedt¹⁴ noted in animals that a much better nutritive state exists when a remnant of the pancreas with its duct is left connected with the duodenum and suggested implantation of the pancreatic duct into the stomach or intestine, whenever possible, in man following pancreaticoduodenectomy. In 1943, Whipple⁴³ recommended the implantation of the stump of the pancreas into the jejunum to improve the existing impaired fat digestion and to avoid the very annoying pancreatic fistula which frequently follows exclusion of the pancreatic secretion. In my own experience pancreatic fistula has not occurred when the stump of the severed pancreas has been anastomosed to the intestine.

Is there any good reason why the end of the divided pancreas should not be united with the intestinal tract? Will future autopsies prove that ascending infections in the pancreas, as a result of pancreaticoenterostomies, shorten the life of patients? Will the proved fibrosis and atrophy of the pancreas following the occlusion of the pancreatic ducts shorten life? Until these questions can be answered, an unqualified opinion concerning the advisability of restoration of the external pancreatic secretion following pancreaticoduodenectomy cannot be given. One can state with assurance that to restore the external pancreatic secretion of the intestinal tract is a physiologic procedure.

CHOICE OF ONE-STAGE OR TWO-STAGE OPERATION

The one-stage operation is preferable if the general condition of the patient will tolerate with reasonable safety such an extensive and prolonged procedure. The earlier patients with periampullary carcinoma come to operation

TABLE VI. MORTALITY RATE OF PANCREATICODUODENECTOMY

		NO. CASES	POST- OPERATIVE DEATHS	POSTOPERATIVE MORTALITY RATE (PER CENT)
Whipple's collected cases to April 1, 1942	Two-stage	41	12	29.2
	One-stage	23	8	34.7
Collected cases April 1, 1942, to Nov. 1, 1944	Two-stage	15	4	26.6
	One-stage	19	6	31.5
Author's added cases*	Two-stage	1	0	0.0
	One-stage	4	1	25.0
Totals	Two-stage	57	16	28.0
	One-stage	46	15	32.6

*Four earlier cases are included in these collected cases.

after the onset of symptoms, the greater the number that will be suitable for the one-stage operation. There will be a relatively large percentage of deeply jaundiced and generally debilitated patients for whom the two-stage operation must be chosen. The first stage of the planned two-stage operation has a sufficiently high mortality to warn the surgeon that the choice of operation must be very carefully made. Statistics to date indicate that the two-stage operation has a slightly lower mortality rate than the one-stage operation (Table VI).

CHOICE OF TECHNIQUE OF PANCREATICODUODENECTOMY

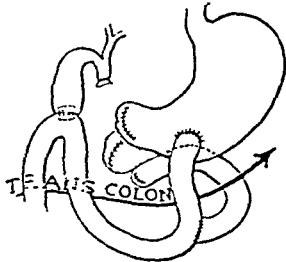
The large number of operative procedures that have been described is obvious evidence that no standard technique has yet been adopted. Almost every surgeon, who has reported his cases, has made some change in the technique (Figs. 1, 2, and 3).

TABLE VII. ADDITIONAL CASES OF CARCINOMA OF AMPULLARY REGION IN HOSPITAL FROM APRIL 1, 1940, TO NOV. 1, 1944

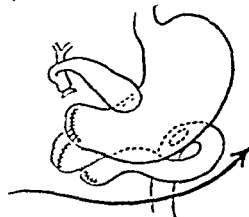
PATIENT	SEX	AGE	TREATMENT	RESULT
J. W.	M	70	Two-stage operation planned: First stage: Cholecystojejunostomy and jejunojejunostomy	Death after first stage on 11th day; autopsy, metastases in liver
H. C.	M	46	Two stage operation: First stage: Choledochoduodenostomy Second stage: Died on operating table	Died during second stage; autopsy, metastases in lymph nodes
F. K.	M	71	Two-stage operation planned: First stage: Section of jejunum and end-to-side jejunostomy and cholecystojejunostomy	Death after first stage on 10th day; autopsy, metastases to liver
C. B.	F	82	Palliative cholecystogastrostomy	Lived 66 days; metastases found at operation
C. L.	M	64	Palliative cholecystogastrostomy	Hospitalized 21 days; metastases found at operation; lived 5 mo.
T. B.	F	71	Clinical diagnosis of carcinoma of head of pancreas	Died on second hospital day; no autopsy
B. S.	M	68	Clinical diagnosis of carcinoma of head of pancreas	Died on fourth hospital day; no autopsy
C. H.	F	69	Clinical diagnosis of carcinoma of head of pancreas	Discharged on fourth hospital day
A. D.	M	53	Autopsy diagnosis of carcinoma of head of pancreas	Died of advanced pulmonary tuberculosis; autopsy, metastases in liver

A few fundamental principles may be recorded which have a bearing upon the choice of operation. They are (1) removal of sufficient tissue about the tumor to include any local infiltration of the tumor and the regional lymph nodes, (2) use of the common duct for anastomosis, when possible, instead of the gall bladder to facilitate drainage of bile and prevent leakage of bile from

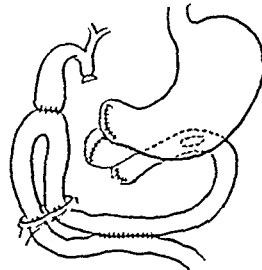
CODIVILLA-1898



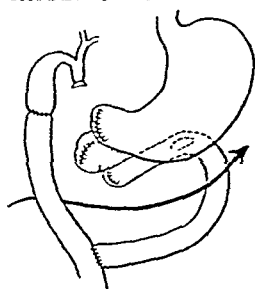
WHIPPLE, PARSONS, + MULLINS-1935



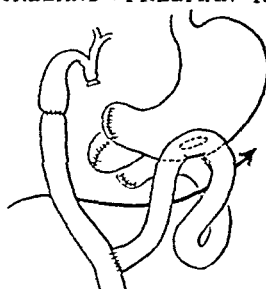
BRUNSCHWIG-1937



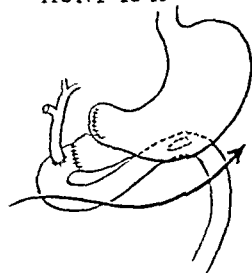
WHIPPLE-1938



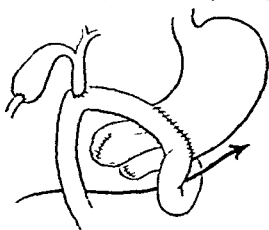
MORELAND + FREEMAN-1941



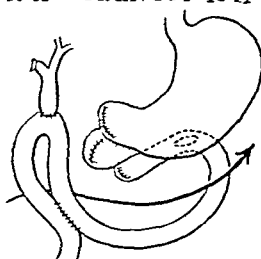
HUNT-1941



TRIMBLE, PARSONS, + SHERMAN-1941



MAINGOT-1941



DENNIS-1942

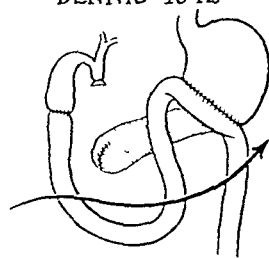


Fig. 1.—Sketches illustrating various techniques of pancreaticoduodenectomy: Codivilla,¹⁰ Whipple, Parsons, and Mullins,⁴⁴ Brunschwig,⁶ Whipple,⁴² Moreland and Freeman,²⁷ Hunt,²³ Trimble, Parsons, and Sherman,⁴⁰ Maingot,²² and Dennis.¹²

a ligated common duct, (3) location of the anastomoses between the gall tract and pancreas and the jejunum proximal to the gastrojejunostomy to prevent infection of the gall tract and pancreas, (4) anastomosis of the pancreas to the jejunum to prevent pancreatic fistula and to restore the external pancreatic secretion to the intestinal tract. The operations of Whipple,⁴³ Poth,³⁵ and Child⁹ incorporate these principles (Fig. 3).

COMMENT ON PERSONAL CASES

In addition to the nine cases listed in Table II and Fig. 3, nine other cases have been observed during the period from April 1, 1940, to Nov. 1, 1944. These cases are listed in Table VII.

A study of all diagnoses of carcinoma of the ampullary region brings up the question of the possible operability and curability of such patients. To estimate the value of any operative treatment, it is reasonable to include all

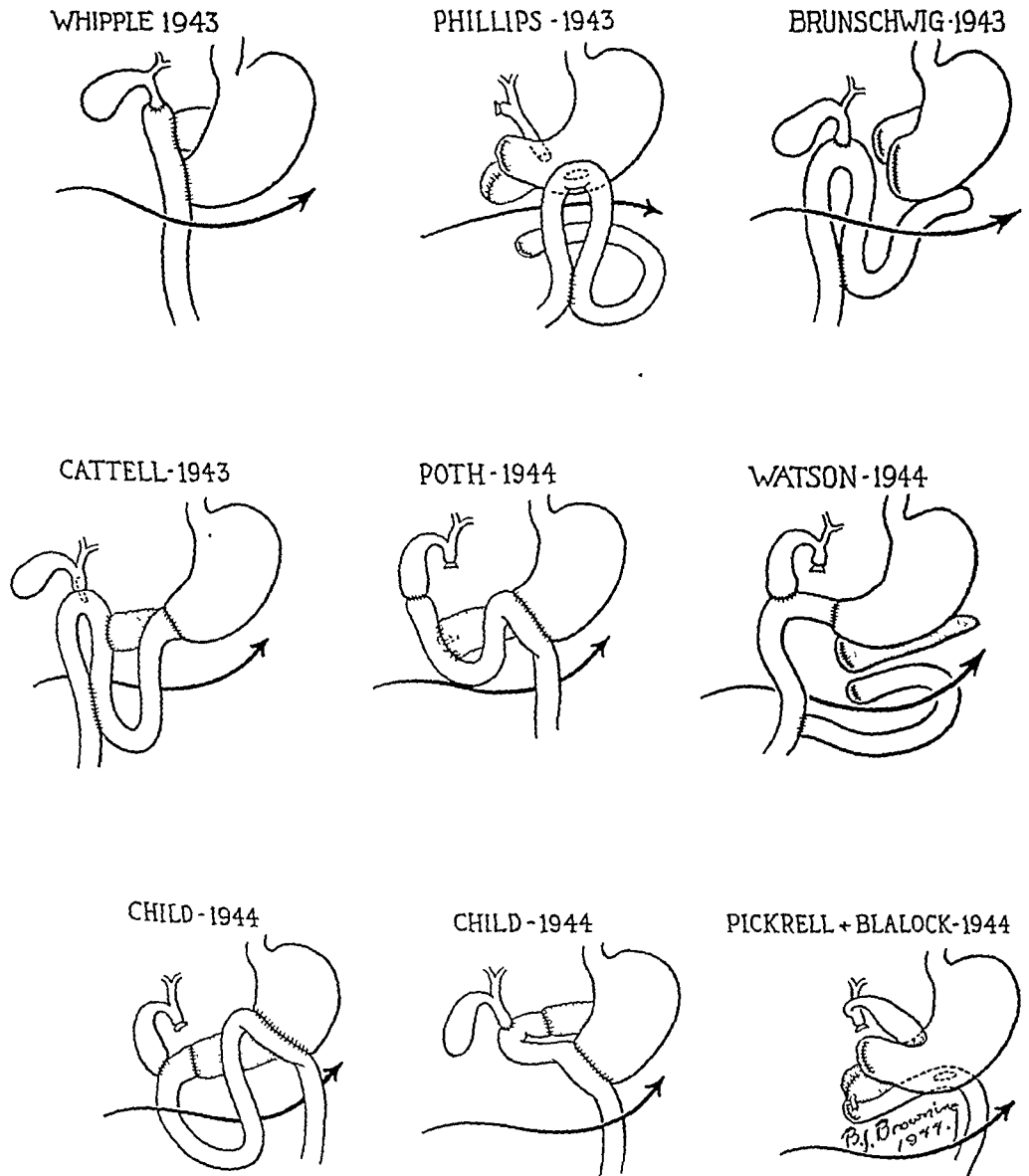


Fig. 2.—Sketches illustrating various techniques of pancreaticoduodenectomy, continued: Whipple,⁴³ Phillips,²³ Brunschwig,⁵ Cattell,⁸ Poth,³⁵ Watson,⁴¹ Child,⁹ and Pickrell and Blalock.³¹

patients having the disease. Of the nine patients listed in Table VII, a two-stage pancreaticoduodenectomy was planned for three. Two died following the first stage and one died on the operating table at the beginning of the second stage. Two patients had palliative cholecystogastrostomies because of extensive metastases. A clinical diagnosis only was made in three cases. Operation was recommended in one of these. Carcinoma of the head of the pancreas was found at autopsy in one deeply jaundiced patient who died of advanced pulmonary

tuberculosis. Of the eighteen patients listed in Tables II and VII, eleven had proved metastases or clinical evidence of metastases. The frequency of metastases in this small number of cases makes one wonder just what percentage of such patients is curable by successful pancreaticoduodenectomy.

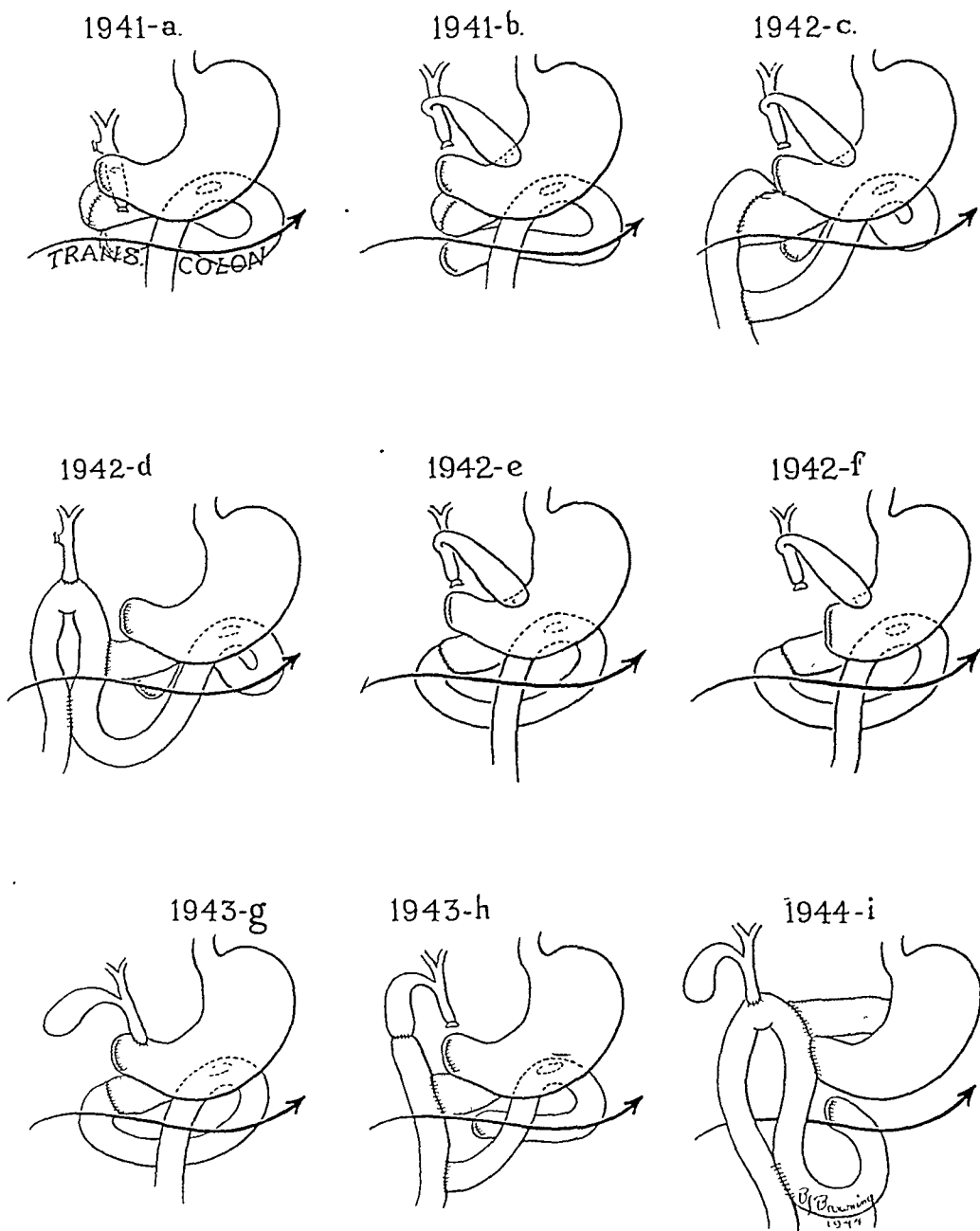


Fig. 3.—Various techniques of pancreaticoduodenectomy used in nine cases in the University of Kansas Hospitals.

CONCLUSIONS

A careful study of each case must be made at the operating table to avoid a needless operation with a high mortality and to select those patients who are considered suitable for a radical operation.

In spite of the rather discouraging results of pancreaticoduodenectomy to date the operation is fundamentally sound and offers the best chance of cure of patients having carcinoma of the ampulla and ampullary region.

The recorded evidence indicates that complete occlusion of the pancreatic ducts will result in fatty infiltration of the liver, reduction in fat and nitrogen absorption in most cases, and fibrosis of the pancreas with atrophy of the acinar tissue. Although there is abundant evidence that patients and animals will live for several years in comparatively good health without the external pancreatic secretion, there has been no valid reason yet recorded why the severed pancreatic stump of pancreaticoduodenectomy should not be united to the intestinal tract. The preservation of the physiology of the pancreas is a very good reason for pancreaticoenterostomy.

The choice of the one-stage or two-stage operation must depend upon the general condition of the patient and the findings at the operating table.

A technique of pancreaticoduodenectomy should be adopted which will reduce the time of operation, minimize ascending infection of the gall tract, prevent pancreatic fistula and biliary fistula, and preserve the normal physiology of digestion.

As in most types of cancer, early diagnosis of carcinoma of the ampullary region is essential to the success of operation. While we cannot credit delay in diagnosis to our medical confreres in all cases, the importance of early diagnosis should be vigorously emphasized and, as Whipple⁴⁵ has so aptly remarked, patients with jaundice should not be "studied to death" before they reach the surgeon.

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THE ORIGIN AND GROWTH OF AN ADENOMA OF THE ISLANDS OF LANGERHANS

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STUDIES of the pathology of adenoma of the islands of Langerhans began in 1902, when Nicholls¹⁰ found at autopsy a small tumor of the pancreas; he gave a detailed description of adenoma of the islands of Langerhans based on a careful gross and microscopic study of this tumor. During the next decade similar reports were made by Helmholtz,⁴ Morse,⁸ Cecil,² Heiberg,³ Rollett,¹⁴ and others, the data for which were obtained at autopsy. A large proportion of the later reports included clinical histories and descriptions of tumors removed surgically. In 1926, Warren¹⁹ suggested the following criteria for the pathologic diagnosis of an adenoma of the islands of Langerhans: (1) that the tumor should be at least 1 mm. in diameter; (2) that the morphology and arrangement of the cells composing the tumor should resemble those of the islands of Langerhans; (3) that the tumor should have a capsule; (4) that the surrounding acinar tissue should be compressed.

Three theories of origin of adenomas of the islands of Langerhans have been proposed. Ssobolew,¹⁷ in 1904, classified a tumorlike structure observed in conjunction with insular hypertrophy as an embryonal rest; Prosorowsky,¹³ in 1913, stated the belief that adenomas of the island tissue, like many other tumors, arose from misplaced embryonal germs. Terbrüggen,¹⁸ in 1931, restated the theory of origin from primitive rests. Many investigators accepted the theory advanced by Rollett,¹⁴ in 1912, that adenomas of the islands of Langerhans arose indirectly from the duct system—from islands whose differentiation was not complete. The origin of adenomas of the islands of Langerhans directly from pre-existing mature islands was postulated by Cecil,² in 1911, and by Priesel,¹² in 1921. It was the opinion of the latter that cystic adenomas arose from the ducts and solid adenomas arose from the islands. He reiterated Bensley's¹ theory that certain cells in the excretory tubules are totipotent. Hickel and Nordmann,⁵ in 1923, in a paper on exocrine adenomas stated the belief that both exocrine and endocrine tumors are derived from the excretory ducts. In one of the tumors described by Smith and Seibel,¹⁶ in 1931, the morphology of the cells, except for the absence of the typical drops of mucin, suggested the possibility of origin from the epithelium of a duct. O'Leary and Womack,¹¹ in 1934, and Whipple and Frantz,²⁰ in 1935, supported the view that islet-cell tumors arise from ducts. Accepting this as the most plausible theory, Laidlaw,⁶ in 1938, proposed "nesidioblastoma" as a concise, descriptive name, indicative of the origin, to replace the cumbersome and perhaps incorrect term "adenoma of the islands of Langerhans."

The origin and development of the capsule of the nesidioblastoma has received little attention. The presence of a capsule of connective tissue was noted by Nicholls¹⁰ (1902), and the same structure has been reported for many of the tumors described. Elastic fibers were mentioned in reports by Rollett,¹⁴

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LeComte,⁷ Priesel,¹² Schneider,¹⁵ and Natali.⁹ Only one author, Warren,¹⁹ specifically mentioned that the capsule of the tumor described by him contained no elastic tissue fibers. An early theory was that pre-existing islands of Langerhans by means of hypertrophy or hyperplasia, or both, encroached upon the less hardy acinar tissue, compressing it and causing atrophy and finally complete destruction of the acinar cells. As the parenchymal cells were destroyed by the steadily growing and advancing tumor, the supporting connective tissue was compressed to form the capsule. The presence or absence of the capsule has been mentioned by various authors, but few of them have reported on any study relative to the capsule or allocated to it any great significance (see Table I). A study of reports of 135 cases, a total of 163 tumors, shows that the capsule was present and complete in 78, incomplete in 25, absent or not mentioned in 60. In the rather wide coverage of the literature, I found no author who suggested that the capsule might be the duct wall, in spite of the fact that many authors stated the belief that adenomas originated from the duct epithelium.

TABLE I. CAPSULE

	NO. OF CASES	NO. TUMORS	CAPSULE PRESENT		CAPSULE NOT REPORTED OR ABSENT
			COMPLETE	INCOMPLETE	
	135	163	77	25	60
Multiple	17	45	16	6	23

The capsule was uniformly complete, incomplete, or absent in all but one of the patients with multiple tumors.

Fig. 1 shows a photomicrograph of a typical adenoma of the islands of Langerhans. The tumor was discovered at autopsy in a man 70 years of age. Symptoms indicated that it had no clinical significance. The adenoma, which was located superficially on the antero-caudal surface of the pancreas, approximately two inches from the splenic end, measured 4.1 by 3.1 by 2.9 mm. The diameter was greatest at the middle, but it was fairly uniform; at each end the tumor was tapered abruptly like the end of a cigar. The entire tumor was sectioned serially, and the sections were variously stained. Staining to bring out the various types of granules was not successful, probably because of improper fixation. The cells of the tumor resembled those of an island of Langerhans. They were cuboidal with a centrally placed nucleus and were arranged in columns and rosettes in close association with numerous blood sinuses and capillaries. The supporting network of connective tissue was heavy. The tumor was surrounded by a complete, rather heavy capsule in which small ducts were visible. Ducts have been noted in capsules by numerous authors. The capsule also contained normal acinar tissue. One can understand the presence of acinar tissue and ducts in the wall of the capsule, as well as the variation in the thickness of the capsule when the entire tumor is studied in serial sections. The outside of the capsule is not smooth like that of a blood vessel, rather it is shaggy and irregular (see Fig. 6). The shaggy, irregular character accounts in part for the variation in the thickness of the capsule and for the presence of acinar tissue and tiny ducts in the capsule. The acinar tissue is not actually embedded in the capsule; a hood of delicate capsular tissue extending from the main capsule embraces but does not surround it. This is diagrammatically illustrated in Fig. 6. If a section were made through the tumor at X the capsule would look thick because the top of the hood of capsular tissue would be cut longitudinally. If the tumor were cut at Y the capsule would look as if it contained

acinar tissue because to the left there is capsular tissue, then acinar tissue, and finally the lateral embrace of the delicate capsular hood (see Fig. 3, *ac*). As one progresses distally by serial sectioning to a point at *Z*, the filament of capsule embracing the acinar tissue disappears; the acinar tissue has joined the main pancreatic tissue and the capsule looks thin and does not contain acinar tissue. Ducts actually penetrate the heavy capsule. At *D* in Fig. 1, one can see a large duct cut in cross section; it is a typical pancreatic duct. The lining epithelial cells here are somewhat columnar, and the duct contains a secretion



Fig. 1.—Typical adenoma of islands of Langerhans, completely surrounded by a capsule in the wall of which small ducts and acinar tissue may be seen. Note cross section of large pancreatic duct *D*. (Hematoxylin and eosin, $\times 30$.)

possessing staining properties of mucin. As one studies more distal sections of the tumor, a duct, which passes from the main duct, *D*, to the capsule of the adenoma, is seen in longitudinal section (Fig. 3). This also is a typical pancreatic duct. It is interesting to note that this duct enters the capsule of the tumor and courses in its wall for a short distance. The cells lining it are more cuboidal than those of the larger duct. In this section the lumen has just been entered and the wall appears thicker than it actually is. Note the wall in the next section.



Fig. 2.—More distal section of the same tumor as is shown in Fig. 1; *D*, pancreatic duct in cross section; *Z*, capsule, *C*, tumor cells. Note small ducts (*d*) in the wall of the large pancreatic duct and also in the capsule. (Hematoxylin and eosin, $\times 75$)



Fig. 3.—Section cut a few microns distal to that shown in Fig. 2. Note the smaller duct (*D*₁) going from the pancreatic duct *D* to the capsule of the adenoma in which it courses for some distance. Mucin was present in these ducts. The wall looks thick because the microtome had just entered the lumen of duct *D*₁ in longitudinal section. (Mucicarmin, $\times 75$.)



Fig. 4.—A section just distal to that shown in Fig. 3. Generous numbers of wavy elastic tissue fibers can be seen in the wall of the pancreatic duct *D*, cut in cross section, in *D*₁, the duct cut in longitudinal section, and in the capsule of the adenoma. The architecture of the wall of the duct and of the capsule is the same. Note the absence of elastic tissue fibers in the acinar tissue. (Weigert's stain, $\times 75$.)

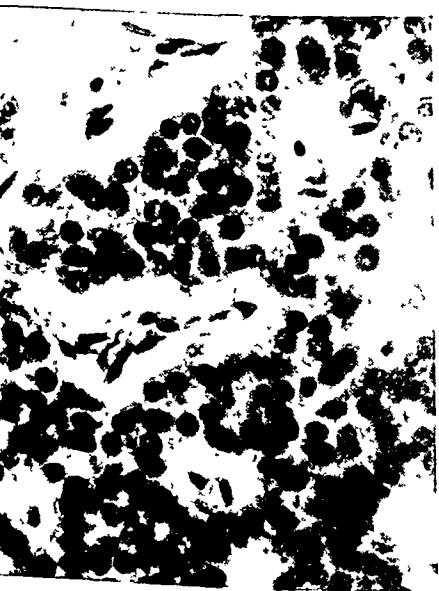


Fig. 5.

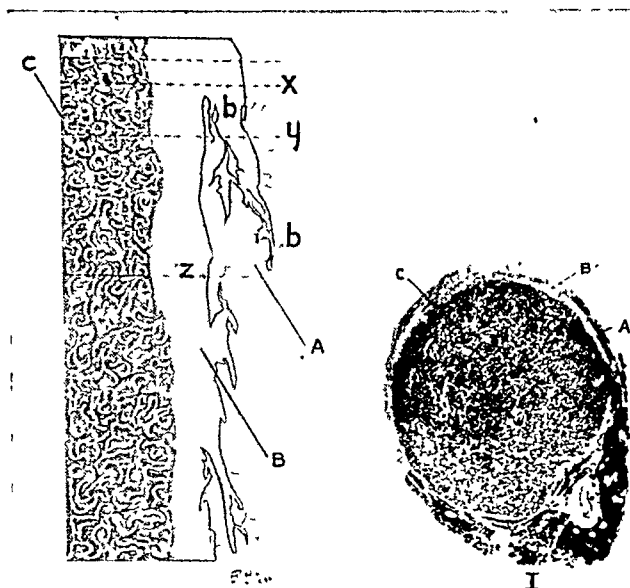


Fig. 6

Fig. 5.—Section showing the tumor cells of the adenoma of the islands of Langerhans. (Hematoxylin and eosin, $\times 500$.)

Fig. 6.—Schematic drawing of a longitudinal section of the capsule of the adenoma. *C*, tumor cells; *B*, the capsule; *A*, acinar tissue. Note the hood or V which *b-b* forms with the capsule and which embraces acinar tissue. A section made at *X* would give the impression of a wide capsule; at *Y* acinar tissue would appear in the capsule (see Fig. 3 *ac*). At *Z* the acinar tissue has joined the main body of acinar tissue.

Insert: Adenoma with capsule in cross section.

Fig. 4 shows a section just distal to that shown in Fig. 3 stained with Weigert's stain. One can see the wavy, elastic tissue fibers interspersed between the collagenous connective tissue elements that form the duct wall. Elastic tissue fibers, which are seen in the cross section of the large duct and in the longitudinal section of the smaller duct, pass into and form a part of the capsule of the adenoma. The capsule itself has a profusion of wavy, elastic tissue fibers. They appear all around the adenoma, wherever the capsule is present. In this single picture one can see that the large pancreatic duct seen in cross section, the smaller duct seen in longitudinal section, and the capsule of the adenoma of the

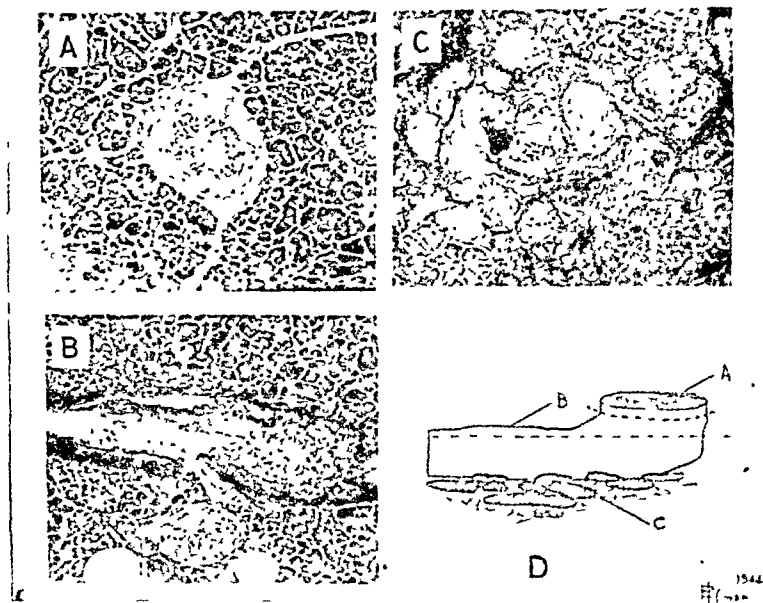


Fig. 7.—A, Cross section of a duct, showing proliferation of the duct epithelium. (Hematoxylin and eosin, $\times 157$.)

B, Section 600 μ distal to Fig. 7A. Longitudinal section of tributary duct showing connective tissue fibers of the duct wall, proliferation of cells, and a small opening or duct leading through the duct wall; an island of cells having the same characteristics as those of the duct epithelium lies close to the small duct. (Van Gieson, $\times 157$.)

C, Section few microns distal to Fig. 7B and just clear of the duct. Many islands of tissue with cells similar to those lining the duct can be seen. (Van Gieson, $\times 157$.)

D, (insert). Schematic drawing showing levels at which sections A, B, and C were taken from the duct and the pancreas.

islands of Langerhans are of the same structure. Consequently, it is my opinion that the capsule of the adenoma of the islands of Langerhans is, in fact, the duct wall. An incomplete capsule can be explained on the basis of overgrowth of the tumor that causes it to break out of the restraining walls of the duct. The presence or absence of the capsule also depends on the point of origin of the adenoma in the duct system (see Fig. 16). If an adenoma originates in the terminal portion of the ducts, the capsule will be absent because there is no wall in this part of the duct system. Illustrations of this type of growth are seen in Figs. 11, 12, and 13. In Fig. 12 one can see a small duct connected with a large islandlike structure from which it, no doubt, took its origin. Many islands are seen near by. Seventy-five per cent of the multiple tumors occur in close proximity. Twenty-five per cent are found in widely separated segments of the pancreas. It should be noted that the duct has no wall. Fig. 13 shows an enlarged island, 1 mm. in diameter, that fulfills the earlier criteria for diagnosis of an adenoma of the islands of Langerhans except that it has no capsule. The absence of a capsule can be explained on the basis that the proliferation began in the duct system where the wall is absent.

Few examples of adenomas in the process of growing or of duct epithelium in a state of proliferation have been reported in the literature. Parts *A*, *B*, and *C* of Fig. 7 show photomicrographs of duct epithelium in a state of proliferation. Fig. 7, *A*, is a cross section of a duct. Note the proliferation of the duct epithelium. In the section shown in Fig. 7, *B*, 600 μ from that in Fig. 7, *A*, the lumen of

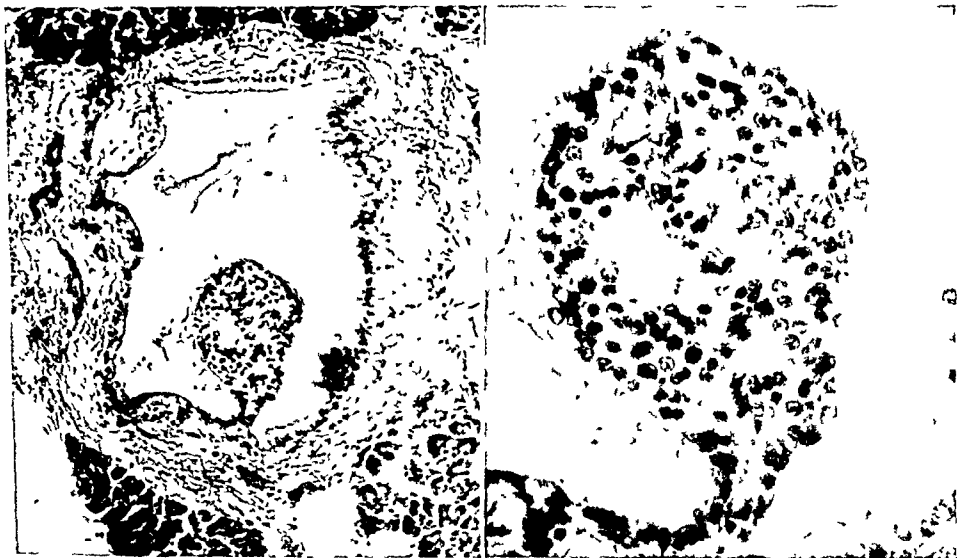


Fig. 8.

Fig. 9.

Fig. 8.—An unusual specimen. The section shows a polyp of islandlike structure growing directly into the lumen of a duct, originating from the duct epithelium. It is easy to conceive that the polyp would grow, fill the duct, and expand into an adenoma. Note the shape of the duct in cross section. (Hematoxylin and eosin, $\times 150$.)

Fig. 9.—The same section enlarged to show the similarity of the cells to those of an island of Langerhans. (Hematoxylin and eosin, $\times 500$.)



Fig. 10.—Another unusual specimen. Note the growth of the duct epithelium; it has practically occluded the lumen of the duct and is now the size of an average normal island of Langerhans. (Hematoxylin and eosin, $\times 157$.)

the same or a tributary duct running at right angles to this was cut longitudinally. The proliferation of the epithelium is still evident and a small tributary duct enters at this level. The same type of proliferation and the same type of cells appear in the tributary and in the large duct. A section made just distal to

the duct is shown in Fig. 7, *C*. There are many islands of cells separated by heavy supporting connective tissue. The cells composing these islands resemble those which were proliferating in the adjacent duct. Fig. 7, *D* shows the levels from which sections *A*, *B*, and *C* were taken.

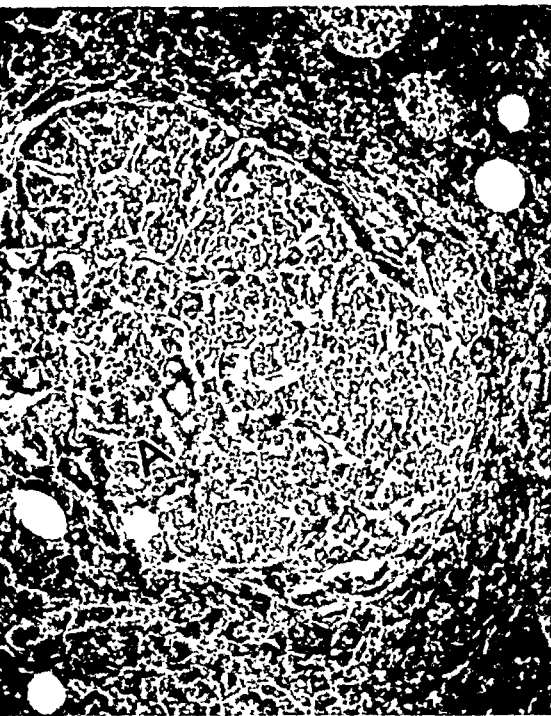


Fig. 11.

Fig. 11.—This isletlike structure measures 1 mm. The acinar tissue surrounding it is compressed. There is no capsule, and a duct, *A*, seen at the center has no wall. (Hematoxylin and eosin, $\times 75$.)



Fig. 12.

Fig. 12.—Section showing a large island with a small duct, *A*, coursing almost to the center of the island. This duct seems to be a tributary of the larger duct *D*. Note islands near by. (Hematoxylin and eosin, $\times 75$.)

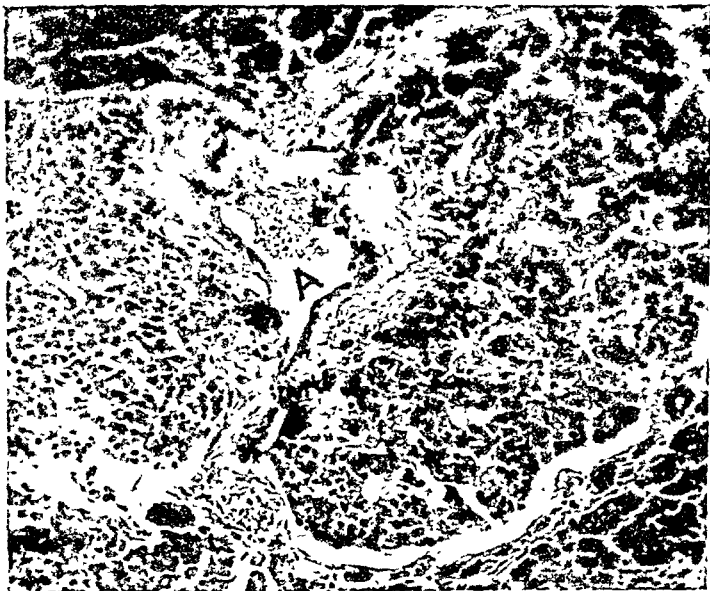


Fig. 13.—Section through an island (1 mm. with a duct, *A*, in its center. (Hematoxylin and eosin, $\times 75$.)

As uncommon as are reports and photomicrographs of proliferating epithelium of the ducts, illustrations or descriptions of an adenoma in the stages of growth are still rarer. I obtained some photomicrographs of rare specimens which I believe can be considered as demonstrating stages in the growth of an adenoma. Figs. 14 and 15 also show proliferating duct epithelium which almost fills the lumen of a duct and the mass of cells measures about $200\ \mu$.

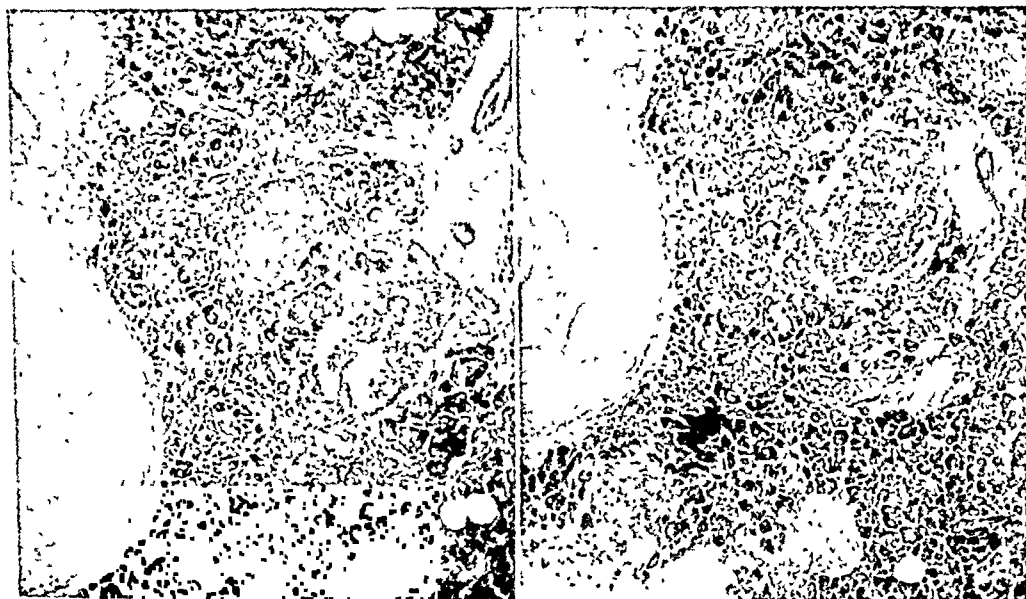


Fig. 14.

Fig. 15.

Fig. 14.—Longitudinal section through a pancreatic duct showing proliferation of epithelium. (Hematoxylin and eosin, $\times 75$.)

Fig. 15.—Same specimen $200\ \mu$ distal. Mass of cells resembles islands of Langerhans in size and appearance. (Hematoxylin and eosin, $\times 75$.)

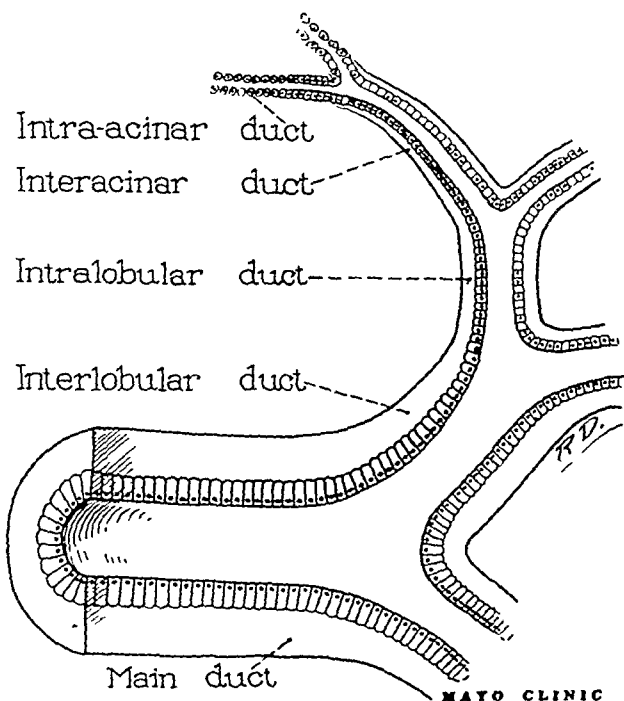


Fig. 16.—Schematic drawing of the duct system. Ducts usually branch at right angles rather than as shown. Terminal ducts show no wall.

Please note that the length of the proliferating mass is a little greater than the diameter of the duct in which it has taken origin.

Fig. 10 presents another unusual specimen. The growth of the duct epithelium has almost occluded the lumen of the duct and is now almost the size

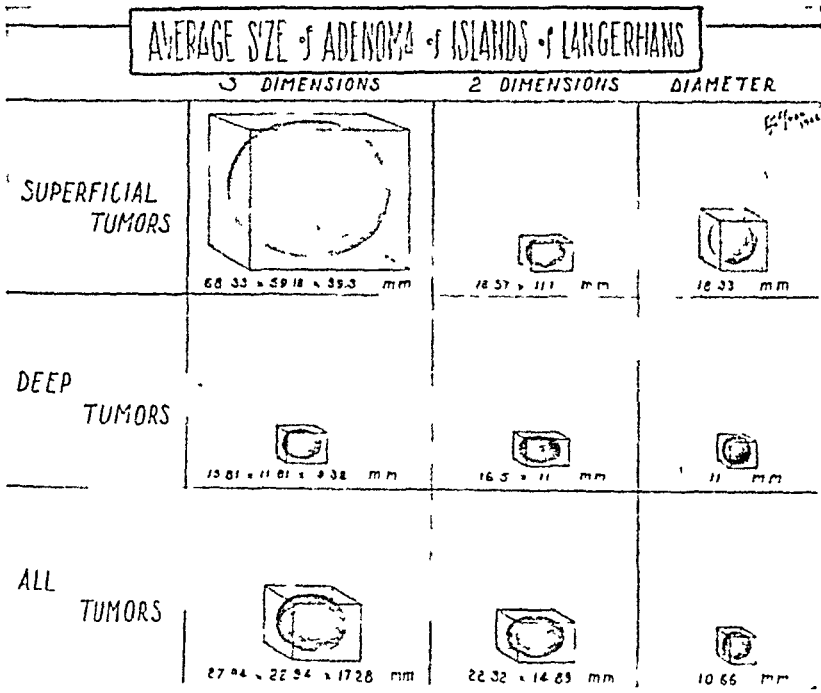


Fig. 17.—Schematic representation of the average size of adenomas of the islands as reported in literature. Some authors gave measurements in three and some in two dimensions, some in diameter only. Averages for each method are recorded and drawn to scale.

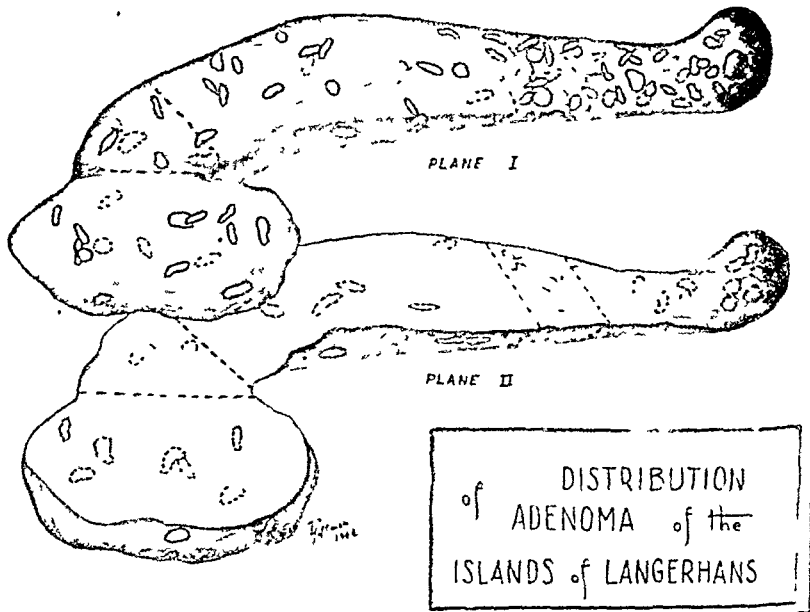


Fig. 18.—Distribution of adenomas reported in the literature. The pancreas has been sectioned sagittally. The superficial tumors are represented in the anterior, the deep in the posterior, section.

of a normal island ($240\ \mu$). The proliferation seems to have taken place sub-epithelially and has pushed the lining epithelium, unbroken, in front of the advancing mass of cells. It is easy to see how, with continued proliferation of cells, the lumen of the duct would be filled and an adenomatous mass would be formed with the duct wall as its capsule. It is also easy to see that the growth would take place with less resistance along the lumen than against the wall; and if this is true, theoretically the length of an adenoma arising in a walled duct would be greater than its cross diameter. The reports of authors who have carefully measured the size of the tumors in three dimensions substantiate this theory (see Table II and Fig. 17).

Fig. 8 shows an unusual specimen—a polyp of islandlike cells arising from the duct epithelium and growing directly into the lumen of the duct. The polyp measures $\frac{1}{3}$ by $\frac{1}{4}$ mm. Fig. 9 shows this polyp under high power to illustrate the great similarity of the cells to those of an island of Langerhans. It is easy to imagine that this polyp could grow, fill the duct, expand into an adenoma, and become surrounded by a capsule or the duct wall. The duct measures 0.8 by 0.7 mm. in cross section, and the shape corresponds roughly to the outline of an average adenoma.

While not strictly within the limits of the subject matter of this paper, there are facts closely enough related to the growth of the adenomas to be permissible for inclusion in the paper, and which, at the same time, I believe will lend considerable interest for surgeons. Of the 135 cases of adenoma reported

TABLE II. AVERAGE SIZE IN MILLIMETERS

TUMORS SITUATED	THREE DIMENSIONS	TWO DIMENSIONS	DIAMETER
Superficially	68 × 59 × 39	16.5 × 11	18
Deep	16 × 12 × 9	16 × 11	11
All (including those whose location was not stated)	28 × 23 × 17	22 × 15	11

in the literature, in 17 cases, or about 8 per cent, multiple adenomas were present. Surgeons must recognize that in 1 of every 10 cases of hyperinsulinism due to adenoma, the tumor will be multiple. In 75 per cent of these cases, the tumors will be found in fairly close proximity to each other; in 25 per cent, the tumors will be found in widely separated areas. The character and pattern of the multiple tumors are very much alike. For example, the capsule was complete, incomplete, or absent, uniformly in all cases of multiple tumors with the exception of one. The distribution of the tumors is diagrammatically shown in Fig. 18. The superficial tumors are presented in the anterior sagittal section; the deep tumors are drawn in the posterior sagittal section. Tumors which were definitely localized are drawn accordingly in the diagram as to position, but not as to size. Many are not accurately described and had to be distributed on the basis of inaccurate knowledge. Table III gives the available data collected from the literature. As one would expect from a knowledge of the distribution of the islets of Langerhans, the tumors predominate in the tail of the pancreas. Tumors which are found in the tail are superficially located in a great majority of the cases. In the head, the majority of the tumors are found deep in the pancreatic tissue. It has occurred to me that the terminal (peripheral) blind-end ducts were more likely to be the seat of adenomas. If so, the interlocking ducts between the dorsal and ventral pancreases might offer an explanation for the predominance of the deep-seated tumors of the head and neck of the pancreas.

TABLE III. LOCATION OF ADENOMA OF ISLANDS OF LANGERHANS

TUMORS	HEAD	JUNCTION HEAD AND BODY	BODY	JUNCTION BODY AND TAIL	TAIL	EXTRA PANCREATIC	NOT LOCALIZED	TOTAL
Number	21	8	18	16	34	6	60	163
Multiple	7		10		11			
Combined	4		2		2			

A drawing has been made to show the relationship in size which exists in tumors found superficially and deeply. Some authors (as they should) measured the tumors in three dimensions, others in two dimensions, and finally, some gave only the diameter. Consequently, in Table II is shown the average size of the adenoma based upon each of the several ways of measuring. Tumors described with comparative sizes were not included. The average size of the superficially placed adenoma measured in three dimensions is four times the size of a similarly deeply placed tumor. The large size of the superficial may be due to an erroneous inclusion of a low-grade malignant adenoma. In general, the superficially placed tumors are larger than those located deep in the pancreatic tissue. There is less resistance to growth. The measurement of tumors in three dimensions shows that the tumors are definitely elongated and that the diameter of a cross section of the tumor shows it somewhat flattened. See shape of duct, Fig. 8.

SUMMARY

An effort has been made to show that the structure of the wall of the pancreatic duct and the wall of the capsule is the same, and, therefore, the capsule is the duct wall and its presence or absence depends upon whether the adenoma took origin in a duct with or without a wall. And finally, the gulf which exists between the theory of origin and a mature adenoma has been bridged by showing the proliferation of the duct epithelium, and intraductal islands of cells representing stages of growth.

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ISLET-CELL TUMORS OF THE PANCREAS

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THE relationship of certain islet-cell tumors of the pancreas to hypoglycemia is now well recognized and interest in this regard has been demonstrated by the increasing number of cases reported in the literature in the last decade. Islet-cell tumors of the pancreas generally conform to the conception of hyperinsulinism which was formulated by Seale Harris. There are generally signs of insulin shock of varying degree with an abnormally low blood sugar level, the symptoms in most instances being relieved by the ingestion of carbohydrate.

The first islet-cell tumor was reported by Nicholls, in 1902, who found a simple adenoma of the pancreas arising from the islands of Langerhans. Later, in 1926, Warren, in reviewing the literature, was able to find only sixteen cases of adenoma but he was able to add four of his own. None of these tumors presented any symptomatology or clinical signs which would have led to their discovery and, as a result, the conclusion drawn was that they were only of academic interest.

The discovery of insulin in 1922, by Banting and Best, was followed by the recognition of insulin shock. In 1924, Seale Harris, observing similar reactions in a limited number of cases, conceived the possibility that hyperinsulinism and hypoglycemia might occur as a result of oversecretion on the part of either hyperplastic islets or tumor of the islands of Langerhans. At this time, however, he called attention to other glands of internal secretion whose action might influence hypoglycemia, such as the thyroid, the anterior lobe of the pituitary, and the adrenals.

The first case showing true evidence of hypoglycemia and hyperinsulinism was reported by Wilder and his associates. In this patient there was a typical picture of insulin shock which failed to respond adequately to the ingestion of carbohydrates. At operation, at a later date, a carcinoma involving the islands of Langerhans was found with metastasis to the liver. Later at necropsy, an assay of the metastasis showed a definite insulin content. Following this, case reports were made by Thalheimer and Murphy, McClenahan and Norris,

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and others. The first islet-cell tumor giving typical signs of hypoglycemia with hyperinsulinism diagnosed and treated successfully by surgery was reported by Howland and his associates. This patient showed an adenoma. Its removal was followed by complete recovery and subsidence of all symptoms. Whipple, in a recent review, was able to report 149 islet-cell tumors showing hypoglycemia. Of these, 106 were considered benign, 28 questionably malignant, and 15 definitely malignant with metastases to the liver.

These tumors are generally single but two or more have been found in approximately 10 per cent of the reported cases, being located principally in the body and tail of the pancreas but they may be found in the head of the gland. In situ these tumors are dark red or purplish in color due to increased vascularity and are firmer than the surrounding tissues. Their size varies but the average is 1 to 2 cm. in diameter. The tumors which are benign are encapsulated as are some of questionable malignancy. They may show signs of degeneration, either hyaline or fibrous, and in some cases are definitely calcified. On microscopic section the cells are typical of islet cells, being edematous, but vary in arrangement and differentiation. In the questionably malignant group there is some congestion of the capsule, and islet cells may be found in the capillary beds. Alpha and beta cells may be demonstrated by special staining.

The symptoms of islet-cell tumor may be hunger, sensation of faintness, perspiration, and vertigo or there may be signs in addition which are related to the nervous system. Wilder has classified the nervous symptoms under three groups: (1) disturbance of the sympathetic nervous system with dizziness, nausea, pallor, and sweating; (2) disturbance of the central nervous system, such as convulsions with tonic and clonic contractures of the extremities; (3) psychic disturbance with anorexia, maniacal seizures, mental confusion, and coma. These attacks frequently occur during periods of fasting or overfatigue, at which time the blood sugar levels are low. There is frequently a rapid response to the ingestion of glucose either by mouth or parenterally.

Whipple has presented a triad which he believes is very useful in differentiating possible islet-cell tumors: (1) attacks of insulin shock coming on during fasting or an overfatigued state; (2) blood sugar findings of 50 mg. per cent or less; (3) prompt relief by the ingestion of glucose. When this triad is present the possibility of islet-cell tumor due to an oversupply of insulin must be seriously considered.

The presence of hypoglycemia presents a diagnostic problem. The influence of the other glands of internal secretion affecting carbohydrate metabolism must be given careful attention. The thyroid can be ruled out frequently by the clinical picture with the findings of dysfunction of the gland including an abnormal basal metabolic rate. In the case of the pituitary, x-ray picture of the skull should show a widening or destruction of the sella turcica, and the presence of headaches with visual disturbance would indicate the presence of a tumor in this region. In the case of the adrenals, we might expect Addison's disease or findings of adrenal tumor itself. The liver, too, should be carefully considered but these cases show evidence of liver damage or insufficiency, the patient manifesting symptoms of acute illness. The glucose tolerance test does not always give evidence which may indicate the definite presence of islet-cell tumors; even the use of alloxan offers no positive aid in diagnosis.

The medical treatment of hyperinsulinism due to suspected islet tumor is avoidance of fatigue and overexertion, and the intake of large quantities of glu-

cose either by ingestion or injection. Mild cases may be benefited and surgery delayed or avoided.

Surgery must be employed in those more severely ill patients who are not adequately responsive to palliative measures. The general condition of the patient should be brought to the best possible level by a high protein, high carbohydrate intake supplemented by plasma and blood transfusions.

The transverse or inverted T incision is particularly suited to operations on the pancreas. The gland may be approached through the gastrohepatic or gastrocolic omentum but in either instance exposure should be adequate. If most of the greater curvature of the stomach is freed and reflected upward, practically the entire anterior surface of the pancreas can be visualized. Islet tumors may be quite obvious or not visible at all and in the latter instance the entire gland should be carefully palpated. In the presence of an obvious adenoma its removal is usually adequate to accomplish a complete relief of symptoms. However, it must be borne in mind that these masses may be multiple, and additional tumors should be removed when present. Several instances are reported in which a patient has required a second operation for removal of an adenoma missed at the first operation. What procedure to employ when a tumor cannot be found is open to debate. The abdomen may be closed and further observation awaited to perform a possible second operation when the tumor is sufficiently developed to permit its location and removal, or an adequate portion of the pancreas may be resected with the idea of cutting down the secretion of insulin similar to the treatment of hyperthyroidism, in the hope that the removed segment of gland may bear the offending tumor. In view of the fact that islet tumors usually invade the body and tail of the pancreas, this is the portion removed. Bruschwig stated concisely that in those patients presenting the essential triad, an exploratory laparotomy is indicated for excision of pancreatic islet-cell adenoma or, failing to find this, a subtotal pancreatectomy should be performed. This advice is also subscribed to by David, Cole, and others. According to David, approximately four-fifths of the gland lying to the left of the mesenteric vessels and weighing about 48 to 72 Gm. should be removed. To facilitate the operation and to guard against hemorrhage Whipple recommended ligation of the splenic vessels and splenectomy. Drainage must be employed to carry off leakage from the cut surface of the pancreas. This secretion, however, is not unduly irritating to the skin as the digestive ferments have not been activated. Holman and his co-workers have reported a number of cases in which extrapancreatic islet adenomas have been the cause of hyperinsulinism and hypoglycemia.

CASE REPORT

Mr. K. M., aged 24 years, whose family history and past history are of no importance, was a discharged soldier from the present world conflict. He was wounded twice in service, from which he recovered in a comparatively short time and was returned to regular infantry duty. He experienced the first symptoms when he became unconscious while on sentry duty. Because of these attacks of unconsciousness he was sent to a hospital and evacuated to the United States. He experienced several attacks during the process of evacuation. In the United States he was studied in army hospitals but no definite diagnosis was arrived at and he was finally discharged as an epileptic.

The patient was sent to the Veterans Hospital for further study and diagnosis. During the examinations it was noted that it was difficult to arouse him in the morning, that he experienced lethargy, drowsiness, and irritability, and was most uncooperative and difficult to manage, so much so that it was necessary to keep him in a lock section. Repeated blood sugar examinations were persistently low and on several occasions the patient went into a deep stupor at which time the blood sugar was found to be as low as 45 mg. per cent. He

In addition, the nuclei did not contain as much chromatin as the nodular masses previously described.

CONCLUSIONS

1. The clinician must be on the alert for that triad of symptoms described by Whipple which indicates the presence of an islet-cell tumor of the pancreas.

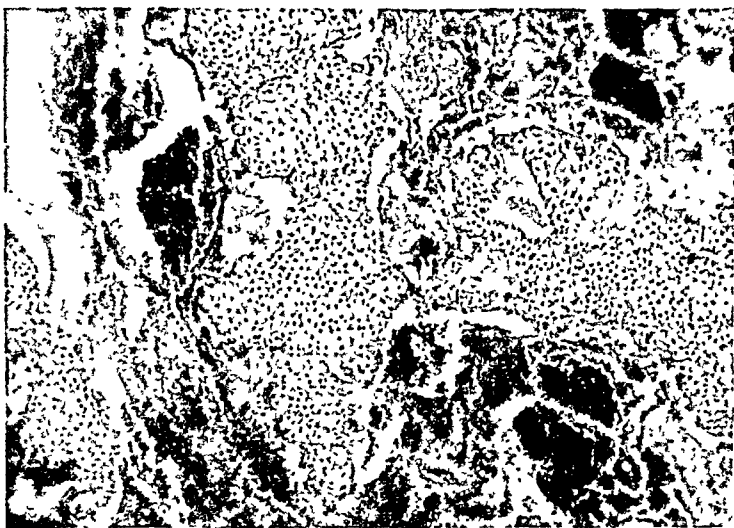


Fig. 4.—High-power view showing characteristic islet tumor cells.



Fig. 5.—An islet tumor about twenty times the size of the normal islet seen in the normal surrounding pancreas.

2. When this triad is present, an operation exploring the pancreas is indicated.

3. Removal of an obvious islet-cell tumor or tumors should be performed. When these cannot be visualized, pancreatic resection may be advisable. The present case report substantiates the latter statement inasmuch as nine islet tumors were found in a pancreas when they could not be demonstrated by vision or by palpation.

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GASTROJEJUNOCOLIC FISTULA

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DURING the ten-year period from 1934 to 1944, forty-seven patients were treated by surgical operation for marginal or jejunal ulcer at the University of Michigan Hospital. Five of these forty-seven patients required an additional operation during this same period because of recurrent gastrojejunal ulceration and one patient was operated upon three times for this same condition. Thus, a total of fifty-four operations was performed upon forty-seven patients. Of the afore-mentioned forty-seven patients, eight or 17 per cent had the serious complication of gastrojejunocolic fistula. It is with this latter group of cases that the present discussion is concerned. This incidence of 17 per cent is slightly lower than that reported by Benedict¹ at the Massachusetts General Hospital, who found the incidence of fistula due to perforation of jejunal ulcer into the colon to be 23.8 per cent in twenty-one patients with jejunal ulcer treated surgically. However, when all of his marginal ulcer cases were considered, that is, those treated both medically and surgically, the incidence of fistula was found to be 13.9 per cent. According to a report by Verbrugge,² the incidence of fistula was 11.36 per cent among eighty-eight jejunal or gastrojejunal ulcers treated surgically at the Mayo Clinic prior to 1924. In a later report from the same clinic Walters and Clagett³ found a gastrojejunocolic fistula to be present in twenty-three instances, or 13.6 per cent of 169 cases

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of gastrojejunal ulcer in which operation was performed during the years 1933 to 1936 inclusive.

Since the experience of any one surgeon in this field is not large, and since the number of cases seen in any one surgical clinic is relatively small, a survey has been made of all of the cases of gastrojejunocolic fistula at the University Hospital since its opening in 1925. During this period from 1925 to 1944, eighteen unmistakable cases of gastrojejunocolic fistula due to ulcer have been encountered. The earlier cases in this group were presented in a preliminary report on this subject by Rife,⁴ in 1938. Fourteen of the eighteen diagnoses were verified by surgical operation. In two of the cases the diagnosis was established beyond any doubt by clinical and roentgenologic evidence. Operation was advised but these patients refused treatment. In one instance, even though a positive diagnosis was made, no operation was advised because of the poor condition of the patient and his advanced age of 72 years. In only one instance was the diagnosis not made during life, being subsequently disclosed at necropsy.

From a study of the cases reported in the literature, it is evident that gastrojejunocolic fistula almost invariably occurs as a complication of a marginal or jejunal ulcer at the site of a gastroenteric anastomosis for duodenal ulcer. The great majority of cases occurs in instances of posterior gastrojejunostomy and much more often following simple short circuit operations rather than in cases of gastrojejunostomy associated with partial gastric resection. In the eighteen cases under discussion, duodenal ulcer was the primary lesion in every instance. It is a well-accepted fact that marginal ulcer rarely occurs following gastroenterostomy for gastric ulcer and is almost unheard of following gastroenterostomy for carcinoma of the stomach. It is often stated that gastrojejunocolic fistula and gastrojejunal ulcer very rarely occur in women, the reason for this being the lower values for gastric acidity in women as compared with men. In a group of fifty-two cases of marginal ulcer reported by Judd,⁵ in 1935, there was but one woman patient. Seventeen of the eighteen patients were men, there being only one woman in the series. While the exact cause of marginal or jejunal ulcer is not known, the prevailing view is that these lesions most often occur in patients whose gastric acidity remains high following operation. This is much more apt to be true in gastroenterostomy or duodenal exclusion operations as contrasted with subtotal gastrectomy. High gastric acidity is also more likely to be present in the younger patients, in patients whose ulcer history is of short duration, and in those who are subjected to operation in the absence of proper indications or before a sufficient period of medical treatment has been tried.

The ages of the patients are given in Table I. Since gastrojejunal ulcer and gastrojejunocolic fistula are, in fact, artificial lesions, the age of the pa-

TABLE I. AGE INCIDENCE

AGE (YEARS)	NO. OF CASES
30 to 39 inclusive	5
40 to 49 inclusive	3
50 to 59 inclusive	7
60 to 69 inclusive	1
70 to 79 inclusive	2

Oldest patient, 72 years.

Youngest patient, 31 years.

Average age, 49 years, 5 months.

TABLE II. AGE AT TIME OF ORIGINAL OPERATION FOR ULCER

AGE (YEARS)	NO. OF CASES
20 to 29 inclusive	4
30 to 39 inclusive	6
40 to 49 inclusive	3
50 to 59 inclusive	4
Unknown years	1

Oldest patient, 58 years.

Youngest patient, 21 years.

Average age, 38 years, 6 months.

tient with this malady is roughly parallel to that of the patient at the time when the primary lesion, that is, duodenal ulcer, was treated by operation. It will be noted that the oldest patient in this series was 72 (two cases) and the youngest patient 31 years, the average age being 49 years and 5 months. The ages of these patients at the time of the original operation for ulcer are given in Table II. Here the oldest patient was 58 and the youngest 21 years, the average age at the time of the original operation being 38 years and 6 months.

The original operations performed for the primary duodenal ulcer are listed in Table III. Of interest is the fact that in all save one, the primary operation to be followed later by a marginal ulcer was a posterior gastroenterostomy. In the remaining case, a posterior gastroenterostomy was originally performed but due to a malfunctioning stoma, a secondary operation was necessitated during the same hospital stay and this corrective procedure consisted of a conservative gastric resection. According to the history in one case, two years following the gastroenterostomy a gastrojejunocolic fistula developed and was repaired elsewhere by a secondary surgical operation the exact nature of which is unknown, and at the time of the operation for the gastrojejunocolic fistula, the only remaining evidence of an earlier surgical procedure was the posterior gastroenterostomy. In spite of experience at this hospital and the experience of others indicating a high incidence of marginal ulcer following duodenal exclusion operations, such as the Devine or the Finsterer procedures, no instances of gastrojejunocolic fistula following such exclusion operations have been observed. Four of the original posterior gastroenterostomies were done at the University Hospital. One of these was performed for an uncomplicated duodenal ulcer and two for duodenal ulcer with pyloric obstruction. The remaining case was thought at operation to be one of nonresectable carcinoma of the pylorus and a palliative gastroenterostomy was performed. This patient remained well and symptom free for six years following the operation, whereupon he developed pain in the lower abdomen associated with the vomiting of blood. A diagnosis of a bleeding marginal ulcer was made and in spite of the fact that diarrhea developed after hospital entry, the diagnosis of gastrojejunocolic fistula was not made and the condition was revealed only at the necropsy. In Table IV is summarized the time interval between the original operation for ulcer and the operation performed for gastrojejunocolic fistula. It shows a great varia-

TABLE III. ORIGINAL OPERATION FOR ULCER

OPERATION	NO. OF CASES
P. G. E.*	10
P. G. E. (University Hospital)	4
P. G. E. and cholecystectomy	1
P. G. E., resection (malfunctioning stoma)	1
P. G. E. and closure acute perforation	1
P. G. E. (Repair "fistula" 2 years later)	1

*P. G. E., posterior gastroenterostomy.

TABLE IV. INTERVAL SINCE ORIGINAL OPERATION FOR ULCER

TIME (YEARS)	NO. OF CASES
Less than 2	2
2 to 5	4
6 to 10	3
11 to 15	6
Over 15	2
Longest interval, 26 years.	Unknown "years," 1.
Shortest interval, 1 year.	Average, 9 years, 6 months.

tion inasmuch as the longest interval was twenty-six years, the shortest interval one year, the average being nine years and six months. The patient was not certain as to how long before his University Hospital entry it was that the original gastroenterostomy had been performed, but it apparently was a matter of many years. A survey of the literature shows a great variation in this time interval between the original operation and the development of gastrojejunal ulcer and gastrojejunocolic fistula. Bornstein and Weinshel⁶ mentioned one case in which a gastrojejunocolic fistula developed twenty-one years following a gastroenterostomy for duodenal ulcer. Probably the longest interval between the original gastroenterostomy and the occurrence of fistula is that recorded by Langemeyer⁷ whose patient developed a gastrojejunocolic fistula forty years after an anterior gastroenterostomy.

In Table V is outlined the duration of the illness at the time of admission in the eighteen cases. For the most part the admission illness was fairly brief in duration, although for the group the average was approximately one year.

TABLE V. DURATION OF ILLNESS AT THE TIME OF ADMISSION

TIME	NO. OF CASES
Less than 3 months	5
3 to 6 months	5
7 to 12 months	2
13 to 18 months	2
19 to 24 months	2
Over 2 years	2
Average, 1 year.	

SYMPTOMS

The clinical diagnosis of gastrojejunocolic fistula is ordinarily not difficult and in our cases was made correctly in all except the one instance already mentioned. The existence of this condition frequently can be suspected from the history alone. The patient, usually a man, gives a history of more or less typical ulcer symptoms for a variable period of time. A diagnosis of duodenal ulcer having been made, an operation, usually a posterior gastroenterostomy, is ultimately performed. Partial or complete relief of the ulcer symptoms follows for a period usually of months, possibly of years. In an analysis of sixty-seven cases of jejunal or anastomotic ulcers occurring following gastroenterostomy in their own clinic, Allen and Welch⁸ found that one-third originated within the first year, and two-thirds within the second year following the primary operation. The beginning of new trouble may be marked by recurrence of the ulcer symptoms due to the recurrent marginal or jejunal ulcer. These symptoms may last for some time before the onset of the typical symptoms of gastrojejunocolic fistula. In other instances, however, there is no clear history indicative of marginal ulcer but the first symptoms of recurrent trouble are those so characteristic of gastrojejunocolic fistula. From a study of the life history of the disease, it would be expected that prior to the onset of the fistula, symptoms of an anas-

tomotic ulcer would usually be present. This, however, was not true in the majority of the cases herein reported, as only six, or one-third, of the eighteen patients gave such a history. The remaining twelve patients in this series apparently were relatively symptom free until the onset of the symptoms of fistula. Of the patients who had marginal ulcer symptoms prior to the fistula, bleeding was one of the most prominent.

Diarrhea.—Diarrhea is probably the most prominent and distressing symptom of gastrojejunocolic fistula and the condition which is chiefly responsible for the weight loss and the debilitated state of these patients. In some cases diarrhea is practically the only complaint, but more commonly this symptom is associated with others, such as abdominal pain, nausea and vomiting, flatulence, and eructations of foul gas described by the patient as having a fecal odor. Not infrequently blood appears in the stools, particularly at the beginning of the symptoms, presumably at the time when the marginal ulcer actually perforates into lumen of the colon. Five of the eighteen patients reported having had bloody or tarry stools on occasions prior to entry. It is said that following perforation, the ulcer itself heals, although in two of the three patients in our series examined at necropsy, multiple ulcers were present in the stomach and jejunum. One of the necropsies was done upon a patient who had not been operated upon and the other was done postoperatively. With the beginning of the trouble, the diarrhea may occur in episodes with comparative freedom from this symptom for brief periods. In most cases at the time of hospital entry, it had become more severe and persistent. Diarrhea was a prominent symptom in all of the eighteen cases and was the chief complaint in thirteen. Pfeiffer and Kent⁹ were of the opinion that the diarrhea is not necessarily due to the entrance of undigested food directly into the colon from the stomach and in many instances even though the diarrhea is severe and persistent, the passage of large quantities of recognizable undigested food is not the rule. In their detailed histories, only six of the patients described undigested food in the stools. As the result of roentgen studies, Pfeiffer and Kent suggested that the diarrhea is really due to the regurgitation of colonic contents into the jejunum. This fecal matter from the colon proves irritating to the jejunum and provokes exceedingly active peristalsis, which in turn accounts for the abdominal cramps and the diarrhea. They stated that in their roentgenologic studies, barium from the stomach entered the colon rather slowly, even when the fistulous opening was large. On the contrary, barium administered by rectum promptly entered the stomach and the jejunum through the fistulous opening.

Vomiting.—Vomiting is probably the second most important symptom of patients with gastrojejunocolic fistula. It is often described as fecal, but as a matter of fact, it is not the stercoraceous vomiting such as is encountered in small bowel obstruction. It undoubtedly plays a considerable role in the dehydration and emaciation of patients and may bring about serious disorders in the body chemistry, such as alkalosis. Nine of the patients in the series gave a history of vomiting as an important symptom and in four of these the vomitus was feculent in character. Four patients who did not give a history of vomiting gave a definite history of fetid eructations.

Weight Loss.—Weight loss is an almost constant finding in these patients and in many instances reaches an extreme degree. Some degree of weight loss was present in all of the eighteen cases, the greatest loss recorded being 60 pounds, whereas the average weight loss was 33.3 pounds. This marked degree of emaciation is one of the important reasons why these patients are such poor

operative risks and why they are susceptible to infection in the peritoneal cavity as the result of contamination by fecal matter at the time of operation. In view of the mechanical nature of the lesion, any great improvement in the state of nutrition prior to operation is difficult or impossible.

Pain.—Pain of some degree is usually present. In those patients who have symptoms of marginal ulcer prior to the onset of fistula symptoms, the pain is usually of the type ascribed to stomal ulcer. Thus, it is more severe and more intractable to medical treatment than the primary ulcer pain and is often situated to the left of, and slightly below, the umbilicus. In the patients with fistula, oftentimes the pain is not characteristic and may be of the type of any colonic lesion, namely, in the lower quadrants of the abdomen. In a certain number of patients, pain appears to be due in part to some degree of mechanical intestinal obstruction. Obstruction may occur in the colon at the site of the perforation, which in turn results in constriction of the transverse colon by scar at this level or it may be due to small bowel obstruction, the obstruction involving the afferent segment of the jejunum employed in the original anastomosis. In still other instances, small bowel obstruction may occur from adhesions of unrelated loops of small bowel to the large inflammatory mass at the site of the fistula.

EXAMINATION

Physical examination on the whole aids but little in arriving at the correct diagnosis. The most important features observed are the emaciation and dehydration and the evidence of multiple vitamin deficiencies. Often a ventral hernia is found at the site of the former operative scar. Palpable masses within the abdomen and areas of localized tenderness are usually absent. Again, there may be signs of incomplete intestinal obstruction. This may occur in episodes. Due to the common occurrence of hypoproteinemia, nutritional edema may be observed. This finding was noted in ten of the forty patients reported by Atwater, Butt, and Priestley.¹⁰

LABORATORY EXAMINATION

Blood.—Anemia of moderate or severe degree is manifested by these patients. Two factors may be responsible. Deficiency of iron in the body due to failure of absorption will account for a hypochromic form of anemia. A deficit in the erythrocyte maturation factor of Castle in the intestine produces a macrocytic type of anemia. Fifty-two per cent of the forty cases studied by Atwater, Butt, and Priestley showed hemoglobin values below the normal range, and blood smears showed macrocytosis in 14 per cent.

Serum Proteins.—Serum protein determinations were made in ten of the cases. In all but one the values for total proteins were below normal. The lowest reading was 5.5 Gm. per cent and the average for this small group of cases was 6.16 Gm. per cent. Atwater, Butt, and Priestley found lowered values for serum proteins in 88 per cent of their patients tested, the lowest value being 3.7 Gm. and the average 4.9 Gm. per cent.

Blood Ascorbic Acid.—Determinations of the concentration of ascorbic acid in the blood were made in a small number of patients. All showed readings considerably below normal, the average reading for this group being 0.30 mg. per cent.

Prothrombin Clotting Time.—Due to the anatomic features involved in gastrojejuno-colic fistula, there is likely to be impaired absorption of vitamin K from the intestinal tract with a resultant hypoprothrombinemia. Because of the

serious consequences at operation, if such a state is not recognized and corrected, the prothrombin clotting time should always be determined prior to operation. Atwater, Butt, and Priestley found a definitely prolonged time in 43 per cent of their cases studied in this manner.

ROENTGENOLOGIC EXAMINATION

Roentgen studies undoubtedly afford the most important means of proving the existence of gastrojejunocolic fistula. The diagnosis is often suggested or made following the administration by mouth of the barium meal when at the fluoroscopic examination barium is seen to enter the colon promptly (Fig. 1). However, when the fistula is small or if the barium enters the colon slowly this finding may be overlooked. As a part of the examination, the barium enema is



Fig. 1—Roentgenogram taken shortly after the ingestion of barium and showing extensive filling of stomach, small bowel, and a portion of the transverse colon. On fluoroscopy the opaque fluid was seen to pass rapidly through a gastroenterostomy opening and resulted in immediate filling of the transverse colon. There was an exquisitely tender point over the stoma.

most helpful and important (Fig. 2). In the present series of cases, roentgenologic studies were carried out in every instance. In one case the examination was incomplete and unsatisfactory due to weakness of the patient and his inability to cooperate during the examination. Of the remaining seventeen cases the gastrojejunocolic fistula was demonstrated in fifteen, whereas in two the roentgen examination showed evidence of obstruction at the gastroenteric stoma. In both of these cases, however, the clinical data afforded convincing evidence of the presence of some type of internal intestinal fistula. Thus, by careful study the diagnosis rarely remains in doubt and with the diagnosis established, a regimen of suitable preoperative care may be instituted and the details of the operative procedure planned in advance.

TREATMENT

Preoperative Preparation.—Due to the cachectic state of these patients, ample time in the hospital before operation for the correction of the several nutritional disorders is essential. In the group of fourteen operative cases under discussion, the shortest period of preoperative preparation was two days, whereas the longest interval before operation was thirty-one days. The average for the group was 12.3 days. Due to the diarrhea and vomiting, there is usually dehydration, hence fluid balance must be restored and subsequently maintained. The vomiting causes chloride loss with a resultant alkalosis. Diarrhea, on the other hand, is apt to be responsible for abnormal sodium losses with



Fig. 2.—Roentgenogram taken following the introduction of barium per rectum. This shows extensive filling of colon, small bowel, and stomach. At the fluoroscopic examination marked spasm was noted in the mid-transverse colon. Small bowel filling occurred at this point and the cecum could not be well demonstrated.

acidosis as a consequence. Because of vomiting and rapid weight loss, ketosis is often present. Vitamin deficiencies are usually multiple and vitamin supplements are indicated. Blood transfusions are important in correcting secondary anemia and hypoproteinemia. None of the fourteen patients was treated by any form of chemotherapy before operation. With sulfasuxidine now available, its use before operation would seem to offer additional protection.

Operation.—The treatment of gastrojejuno-colic fistula recommended by most surgeons in the earlier days consisted of disconnection of the three structures involved with closure of each and restoration to normal. Sometimes a pyloroplasty was added. The mortality was high due to the poor nutritional state of these patients and the more or less inevitable soiling of the peritoneum with fecal matter at the time of the operation. In order to solve this problem, a number of special procedures has been devised. Allen¹¹ has employed success-

fully a method of aseptic closure of the stomach and jejunum with aseptic resection of the involved segment of colon. This undoubtedly is of value in some of the smaller fistulas but does not seem to lend itself well to the larger and more complicated ones. Findlay¹² has advised a multistage operation utilizing the Mikulicz principle. The involved loop of transverse colon with the jejunal stump attached is exteriorized and subsequently removed. Scrimger¹³ and Estes¹⁴ have suggested gastric resection with exclusion of the fistula, which may be done with exenteration of the mucosa of the cuff of remaining stomach attached to the intestine. Of the more recent suggestions proposed, two of the most outstanding are those of Lahey and Marshall¹⁵ and of Pfeiffer and Kent. The former propose a planned two-stage procedure. At the first stage the terminal ileum is transected, the distal end closed and dropped back into the abdominal cavity. The distal end of the proximal segment is then anastomosed side-to-side to the upper descending colon. By this procedure the intestinal stream is rerouted around the colic fistula, thereby excluding the involved segment of colon from the digestive tract and thus reducing to a minimum the contamination from the lower reaches of the intestine. The functional activity of the bowel is restored before the second stage, which is carried out about three months later. At this session, a block resection of the terminal ileum, right colon, transverse colon, and distal two-thirds of the stomach is performed. This procedure has been used in eight cases with one death. More recently Lahey¹⁶ has reported one case in which, following the first stage procedure, the fistula healed spontaneously. While in his experience other fistulas have not closed spontaneously, he suggested that possibly a longer interval between stages should be allowed and that perhaps by so doing certain other fistulas might close spontaneously, thereby avoiding the necessity of a second stage.

Another suggestion in recent years and one that has received enthusiastic endorsement by many leading surgeons is the plan proposed by Pfeiffer and Kent in 1939. As the result of roentgenologic fluoroscopic examinations, they observed that the passage of material from the stomach into the colon is slow and the amount small. On the contrary, the regurgitation of colonic contents into the stomach and jejunum is rapid and provokes violent peristalsis due to the irritating effect of fecal matter in the jejunum and this in turn accounts for the diarrhea. Pfeiffer and Kent, therefore, performed a complete ascending colostomy as a first stage procedure. A remarkable improvement following this operation is reported. The patients gain in weight and in general health, and the second stage can be performed several months later. At this time a marked subsidence in the inflammatory reaction at the site of the fistula has taken place. In some of their cases, the second stage consisted of restoration to normal and in others of disconnection with gastric resection.

Operation.—In Table VI are given the various operative procedures employed in the fourteen patients treated surgically. In all of these cases the treatment has consisted of a one-stage direct attack. Obviously, no single procedure can be used in all cases as evinced by this list.

Recurrent gastrojejunal ulceration following gastrojejunostomy may occur as a true stomal ulcer situated directly at the anastomosis or as a jejunal ulcer located a variable distance from the anastomosis but practically always distal to it. Similarly, when fistula formation takes place, it may exist in either of these two forms. In only one of the fifteen cases in which the fistula was examined at operation or necropsy was there a true jejunocolic fistula. In this case the fistula was found 18 cm. distal to the gastroenterostomy. Here the

TABLE VI. OPERATIONS PERFORMED FOR REPAIR OF FISTULA

OPERATION	NO. OF CASES
Gastric resection Resection jejunum Closure colon	2
Gastric resection Closure jejunum Closure colon	2
Restoration, triple closure	5
Restoration, triple closure } Pyloroplasty	2
Disconnection Resection jejunum Closure stomach Closure colon	1
(Postoperative polya) Disconnection Closure colon Reanastomosis stomach to jejunum Jejunojejunostomy	1
Separation jejunocolic fistula Closure jejunum Closure colon (Gastroenterostomy left intact)	1

surgical problem was relatively simple. The gastroenterostomy was left intact and a separation of the jejunum from the colon with closure of each of these structures was carried out. Ten of the remaining fourteen cases exemplified true gastrojejunocolic fistula while the remaining four evidently represented a complication of a jejunal ulcer which had developed only a few centimeters distal to the anastomosis. Because of the proximity of these latter jejunocolic fistulas to the gastroenterostomy, the surgical problem of repair was essentially the same as in the former group.

The size of the fistulous opening may vary considerably. In the fifteen cases, notes regarding the size are available in twelve. The largest opening was 6 cm. in diameter and the smallest 0.5 cm., the average being approximately 4 cm.

While gastric resection is undoubtedly desirable in preventing reactivation of the ulcer at a later date, it was performed in only four of the cases, the simpler procedures of restoration or restoration with pyloroplasty being adopted for the remainder of the group.

In the fourteen surgical cases, there were two operative deaths or a mortality of 14.3 per cent (Table VII). These fatal cases were the first and fourth in the series when the cases are arranged in chronologic order. The last ten consecutive operations have been performed without a fatality. One of the two fatalities involved a gastric resection, whereas the second consisted of a restoration with pyloroplasty only. The first patient died on the tenth postoperative day of peritonitis due to leakage at the suture line in the closed colon. The second death occurred on the eighteenth postoperative day, the patient having done well until that time. He suddenly went into shock and died shortly afterward.

TABLE VII. GASTROJEJUNOCOLIC FISTULA (14 OPERATIONS), OPERATIVE DEATHS (2), AND MORTALITY (14.3 PER CENT)

	OPERATION	NECROPSY
(1) 10th day	Gastric resection, resection jejunum, closure colon	General peritonitis Leakage of suture line in colon
(2) 18th day	Disconnection, closure stomach, Closure jejunum, closure colon, Finney pyloroplasty	Lung abscess, right lower lobe, with perforation into pleural cavity; all suture lines intact

Necropsy showed that death was due to the rupture of a lung abscess into the pleural cavity. Necropsy examination was done in both of these fatal cases. While every effort should be made to avoid contamination of the field at the time of operation, this is not always possible. Aseptic closures or anastomoses should be used if feasible. It should be remembered that the peritoneum has a strong defensive power against infection, although it undoubtedly is lessened in these debilitated patients. Peritonitis usually occurs from continued contamination from a leaking suture line or anastomosis, rather than from a single contamination. In this series of cases, intraperitoneal sulfonamide therapy was not employed. The status of the sulfonamide drugs intraperitoneally is not yet fully evaluated. In general this type of therapy has been used far less, with added experience in other related conditions, such as the surgery of the colon for carcinoma or chronic ulcerative colitis. In such cases unless there is gross contamination with extensive soiling of the peritoneal surfaces, intraperitoneal sulfanilamide or sulfathiazole is not now employed. As far as the abdominal wound is concerned, the most vulnerable tissue to infection is the subcutaneous fat, and wound infection in such cases is not infrequent. Wound sepsis occurred in six of the cases but fortunately was not severe in any. It is now believed that in all of these cases the method of delayed primary closure of the wound as proposed by Collier and Valk¹⁷ should be employed.

END RESULTS

The end results in the fourteen cases are summarized in Table VIII. It will be noted that all three of the patients who survived an operation including gastric resection have remained well and free of ulcer symptoms. Of the nine

TABLE VIII. FOLLOW-UP STUDIES IN TWELVE CASES

RESULTS IN NINE OPERATIONS NOT INVOLVING GASTRIC RESECTION (FOLLOWED 3 TO 10 YEARS)	NO. OF CASES
End results	
Good	4
Recurrence of ulcer symptoms (Reoperation, 3)	5
RESULTS IN THREE OPERATIONS INVOLVING GASTRIC RESECTION	
End results	
Good	3

patients surviving the more conservative procedures, only four were well and symptom free. Five patients in this group developed definite recurrence of their old ulcer symptoms. Three of these patients subsequently returned to the hospital for further operative treatment (Table IX). The first case was one in which a conservative Polya resection had been done secondary to a gastroenterostomy complicated by a malfunctioning stoma. Recurrence of symptoms

TABLE IX. CASES REQUIRING SUBSEQUENT SURGICAL TREATMENT FOR ULCER

(1) 4/10/34 (Postoperative polya) Disconnection Closure colon Reanastomosis stomach to jejunum	7/20/34 Excision marginal ulcer Resection jejunum reanastomosis Jejunojejunostomy
(2) 1/11/37 Restoration	3/18/38 Devine exclusion operation for reactivated duodenal ulcer
(3) 2/10/39 Restoration	3/18/41 Gastric resection for reactivated duodenal ulcer (Hofmeister)

occurred a short time following discharge from the hospital and three months after the original operation for fistula, a secondary operation was performed. At this time the new marginal ulcer was excised and a restoration of the Polya anastomosis made. The jejunum at the site of the marginal ulcer was resected and an end-to-end anastomosis performed. Inasmuch as there tended to be some angulation of the jejunum due to adhesions, an additional jejunojejunostomy was performed. The second patient, approximately one year after a restoration operation, required further surgical therapy because of recurrence of the original ulcer symptoms. The original duodenal ulcer became reactivated and progressed to a stage of obstruction; accordingly, reoperation was necessary. Because of dense adhesions at the site of the original ulcer, a Devine exclusion operation was performed. The third patient, approximately two years after a restoration operation for fistula, developed recurrent symptoms from the original ulcer. These were sufficiently severe to demand further surgical therapy. At this secondary operation, the conventional type of subtotal gastrectomy according to the Hofmeister technique was carried out.

It is apparent that the best operation for the correction of gastrojejuno-colic fistula is one in which subtotal gastrectomy is performed. However, with the possible exception of the stage operations of Lahey and Pfeiffer and Kent this often is not feasible or safe. Since simple restoration to normal has afforded complete relief in four of nine patients, this method has a definite place in the treatment of certain of these fistulas. This is particularly true inasmuch as many of these patients had meager indications for the original operation as compared with present-day standards. Moreover, should recurrence of the original ulcer take place, the more desirable operation may be performed with a patient in sufficiently good physical condition to withstand it. This is evidenced by that fact that there were no deaths among the three patients upon whom radical operations were subsequently performed.

OTHER GASTROENTERIC FISTULAS PRESENTING SIMILAR PROBLEMS

During the period of time covered in this report, certain other gastro-colonic fistulas due to primary disease were encountered (Table X). Four of these cases presenting somewhat similar problems were instances of primary carcinoma of the stomach in which spontaneous perforation into the transverse colon had taken place. In three cases exploration was carried out but the lesion was found to be hopelessly inoperable. In the remaining case of gastric carcinoma with gastrocolic fistula, a block resection of the involved segment of colon and lower portion of the stomach was successfully carried out. At the latest report, over two years later, this patient was free of recurrence. There was one case of carcinoma of the transverse colon with perforation into the stomach and a resultant gastrocolic fistula. Here no operation was advised. A single example was found of gastrocolic fistula secondary to tuberculous enteritis. This patient had pulmonary and intestinal tuberculosis and upon roentgen examination was found to have a gastrocolic fistula involving the stomach and the upper descending colon. Surgical treatment was not advised.

TABLE X. GASTROCOLIC FISTULAS DUE TO PRIMARY DISEASE

LESION	NO. OF CASES
Tuberculosis (pulmonary—intestinal)	1 No operation
Carcinoma of transverse colon	1 No operation
Carcinoma of stomach	3 Exploration only
Carcinoma of stomach	1 Block resection, recovery

A small but interesting group of cases is the one of gastroenteric fistula due to surgical errors. Four such cases have been encountered (Table XI). The first of these was one of gastrocolostomy, the original surgical operation having been performed five and one-half years previously for a duodenal ulcer with pyloric obstruction. Before leaving the hospital the patient complained

TABLE XI. GASTROENTERIC FISTULAS DUE TO SURGICAL ERRORS

<i>Gastrocolostomy</i>	
Duodenal ulcer, obstruction	Disestablishment, cure
Operation, 5½ years previously	
Vomiting, diarrhea since	
<i>Gastroileostomy</i>	
Duodenal ulcer, acute perforation	Disestablishment, cure
Operation, 3 years previously	
Diarrhea since	
<i>Gastroileostomy</i>	
Duodenal obstruction	Disestablishment, cure
Operation, 7½ years previously	
Diarrhea since	
<i>Gastroileostomy</i>	
"Ulcers"	Disestablishment, gastric resec-
Operation, 15 years previously	tion (Finsterer), death
Obstructive symptoms	

of fecal vomiting and ever since the operation had continued to have both vomiting and diarrhea. At the time of the second operation, an anastomosis was found to have been made between the greater curvature of the stomach and the distal transverse colon. The treatment consisted of disestablishment of the anastomosis and the patient promptly improved, subsequently remaining well. Three examples of gastroileostomy were encountered. All of the original operations had been performed for duodenal ulcer. Two of these patients had had diarrhea dating from the time of the original operation. The other patient had had a gastroenterostomy fifteen years before and for a number of years following it had symptoms of partial or incomplete small bowel obstruction. Diarrhea was not an important symptom in this case. In two of these cases of gastroileostomy the treatment consisted of disestablishment with prompt recovery. In the remaining case, the anastomosis was disconnected and a gastric resection by the Finsterer method was performed. Death occurred on the ninth day, from peritonitis. Necropsy disclosed that this was due to leakage of the closed distal antral end of the stomach.

SUMMARY

1. Forty-seven patients with marginal or jejunal ulcer were treated surgically at the University Hospital during the period 1934 to 1944. Eight patients, or 17 per cent of the surgical cases, had the serious complication of gastrojejunal fistula.

2. During the period 1925 to 1944, eighteen unmistakable cases of gastrojejunal fistula have been observed. Fourteen of these patients were treated by surgical operation.

3. All of these cases of gastrojejunal fistula represented a late complication of posterior gastroenterostomy for duodenal ulcer.

4. The longest interval between the original operation for ulcer and the hospital entry for fistula was twenty-six years; the shortest interval was one year and the average time nine years and six months.

5. Nearly all patients exhibited serious nutritional disturbances requiring

intensive preoperative treatment. The time spent in the hospital prior to operation ranged from two to thirty-one days, the average time being 12.3 days.

6. The surgical operation in all cases consisted of a one-stage procedure. In ten instances a restorative type of operation was performed, whereas in four cases, gastric resection was included. There was one postoperative death in each group, or a mortality of 14.3 per cent for the entire series.

7. Follow-up studies showed that all patients who survived operations involving gastric resection had good results, whereas, only four of the nine patients surviving the more conservative operative procedures remained free of ulcer symptoms. Three of the five patients with recurrent ulcer subsequently required further surgical therapy. No deaths occurred among these patients who later required reoperation. While gastric resection is ordinarily desirable at the time of the operation for the repair of the fistulas, it is not always feasible or safe. Restoration of the tract to normal, therefore, is a useful procedure in certain cases. This is particularly true inasmuch as many of the original gastroenterostomies were performed upon meager indications as judged by present-day standards. If further surgery for recurrence of the ulcer later becomes necessary in certain cases, subtotal gastrectomy can be carried out upon a patient in good condition with a very low mortality.

8. Gastrocolic fistulas due to primary disease of the stomach or colon are discussed. These patients present similar problems in preoperative care and in certain matters of surgical technique.

9. A small group of gastroenteric fistulas due to surgical errors at the time of the original operation for ulcer is considered briefly.

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CARCINOMA OF SIGMOID AND RECTOSIGMOID INVOLVING URINARY BLADDER

SURGICAL MANAGEMENT IN SIXTY-FOUR CASES

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SOME carcinomas of the sigmoid and rectosigmoid give rise early in their course to widespread metastatic growths. Others, over a period of many months or even years, grow to large size, perforate the confines of the bowel, invade adjacent tissues and organs, and cause death without extension to more distant parts of the body.

At present, surgical therapy for carcinoma of the sigmoid and rectosigmoid with distant metastasis is amenable only to palliative treatment. However, the condition is seldom inoperable because of local extension of the disease. When the uterus, ovaries, or fallopian tubes are involved secondarily these organs, with the diseased portion of intestine, can be removed readily. If one ureter is involved, it can be excised provided the opposite kidney and ureter are functioning normally. Portions of the abdominal wall, spermatic or ovarian vessels, common iliac vein and segments of small intestine that are secondarily infiltrated with carcinoma can be extirpated with the primary growth. However, if the urinary bladder is involved the difficulties of resection are increased. It therefore seems advisable to point out some of the problems associated with carcinoma of the sigmoid and rectosigmoid involving the urinary bladder and to review our experiences with its surgical management. This study is based on sixty-four consecutive cases, in which operation was performed by the senior author in the years 1931 to 1943, inclusive.

DIAGNOSIS

It is often difficult or impossible to detect preoperatively early invasion of the urinary bladder by a malignant process located in the sigmoid or rectosigmoid. Slight involvement of this organ usually is not evident on clinical or laboratory examinations and most often is discovered on surgical exploration.

If extensive involvement of the urinary bladder is present, there may be distressing urinary symptoms to aid the clinician in establishing the diagnosis preoperatively. Pain and discomfort in the bladder, relieved by the passage of flatus or stool, is characteristic. Nocturia, frequency and urgency of urination may be present. If the malignant process invades the lumen of the bladder, a colovesical fistula may ensue. In such instances the passage of gas and feces by way of the urethra establishes the diagnosis of enterovesical fistula. In one of our cases gross hematuria was the only complaint. In the usual history, however, the symptoms referable to the bowel so completely overshadow those referable to the urinary tract that the latter are overlooked unless a careful report is obtained.

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In a few cases of extensive invasion of the urinary bladder it is impossible even by careful questioning to elicit a history of urinary symptoms. In these cases, however, the presence of pyuria may suggest to the clinician the possibility of secondary involvement of the urinary bladder. In twenty-one of the sixty-four cases on which this paper is based, in which the entire vesical wall was invaded by carcinoma, eleven (50 per cent) patients had a significant degree of pyuria preoperatively. Proctoscopic examination and roentgenologic investigation of the colon after a barium enema may reveal fixation of the intestinal lesion in the region of the urinary bladder and thus aid in establishing the diagnosis.

When secondary invasion of the urinary bladder is suspected preoperatively the patient should undergo thorough urologic investigation. Cystoscopic examination aids in determining the extent and situation of the malignant process. Carcinomas of the sigmoid or rectosigmoid that involve the urinary bladder usually involve the dome or posterior wall. In these cases the results of surgical measures have been satisfactory. When the malignant process extends downward, however, and cystoscopic examination reveals extensive invasion of the region of the trigone, the condition is one which is ordinarily not amenable to surgical therapy. Excretory urograms also provide valuable information if, during operation, one ureter must be excised in order to remove the growth.

PREOPERATIVE PREPARATION

The patient should be hospitalized preoperatively for a sufficient period of time to permit proper evaluation of, and improvement in, his general condition. Urinary antiseptics may be administered. Appropriate procedures should be instituted concomitantly to prepare the bowel for surgical operation. Retained fecal material can be eliminated by the use of a saline laxative and enemas of warm tap water. The bulk of the stools can be reduced by a non-residue type of diet. Coliform bacteria in the intestinal contents can be reduced in number, or eliminated, by the administration of large doses of succinylsulfathiazole for at least three days prior to operation.

SURGICAL TECHNIQUE

An incision of the splitting or retracting type, which provides optimal exposure, is made in the lower left rectus muscle. If abdominal exploration does not reveal hepatic or other distant metastatic growths, resection can be undertaken immediately.

Resection of the bladder is performed first (Fig. 1). This is begun by making an incision through the uninvolved portion of the wall of the bladder, adjacent to the lesion, high up on the dome and away from the trigone. The leakage of urine can be controlled almost completely by catheterization of the patient immediately preoperatively and by maintenance of constant suction in the pelvis during the operation. The involved portion of bladder is next resected, the incision being carried downward and completely around the affected portion. In this manner, one-half or more of the bladder can be removed. If the trigone is visualized soon after the bladder is opened there is little danger of injury to important structures located in that region.

The opening in the bladder thus produced is then allowed to remain. Constant suction is instituted to avoid any undue urinary spillage.

The involved portion of intestine is resected next, for these reasons: (1) The vesical portion of the fistulous tract now lies free in the pelvis and, if a colovesical fistula exists, serious fecal contamination is a possibility. (2) The

bladder usually is closed around a suprapubic cystostomy tube, which, if inserted before the intestinal segment is resected, is kept out of the operative field with difficulty. (3) Further mobilization of the peritoneum of the bladder may be necessary in order to reperitonealize the pelvic floor. If the bladder is closed prematurely the suture line may be disturbed by this maneuver.

The primary lesion is removed by resection of an uninvolved segment of intestine proximal to the tumor, a lesser amount distal to it, and a large wedge of the adjacent mesentery (Fig. 2). If the distal portion of the bowel remaining after such a resection does not extend above the brim of the true pelvis, the superior hemorrhoidal vessels always are included in the resection. The distal segment will receive an adequate blood supply from the middle and inferior hemorrhoidal arteries, and by removing the superior hemorrhoidal vessels a more thorough extirpation of adjacent lymph nodes can be obtained.

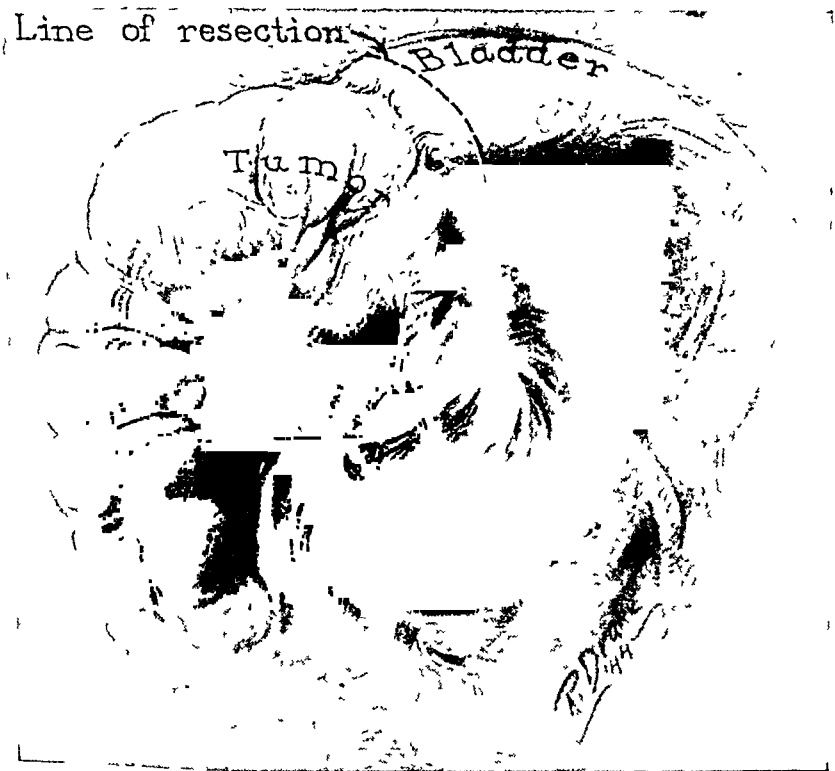


Fig. 1.—A large perforating carcinoma of the lower portion of the sigmoid is firmly adherent to the urinary bladder. Dotted line indicates proposed line of resection of bladder.

After resection is completed, a decision must be made concerning the disposition of the two remaining cut ends of intestine. If both segments are long enough to permit bringing them into apposition on the anterior abdominal wall, an exteriorization type of procedure can be employed (Case 1). In this operation the two ends of bowel emerge from the abdomen through the primary incision or through a stab incision and are held in position by a three-bladed clamp. If the distal segment of intestine is too short to reach to the abdominal wall but the two ends can be approximated (Case 2), the operation is completed as in the so-called "anterior resection" (Fig. 3, inset). Curved rubber-covered clamps are used and end-to-end colocolostomy is performed. A single row of interrupted catgut sutures usually suffices for the posterior part of the anastomosis. The anterior part of the anastomosis is completed with two rows of running catgut sutures. Whenever such an anastomosis is made low in the in-

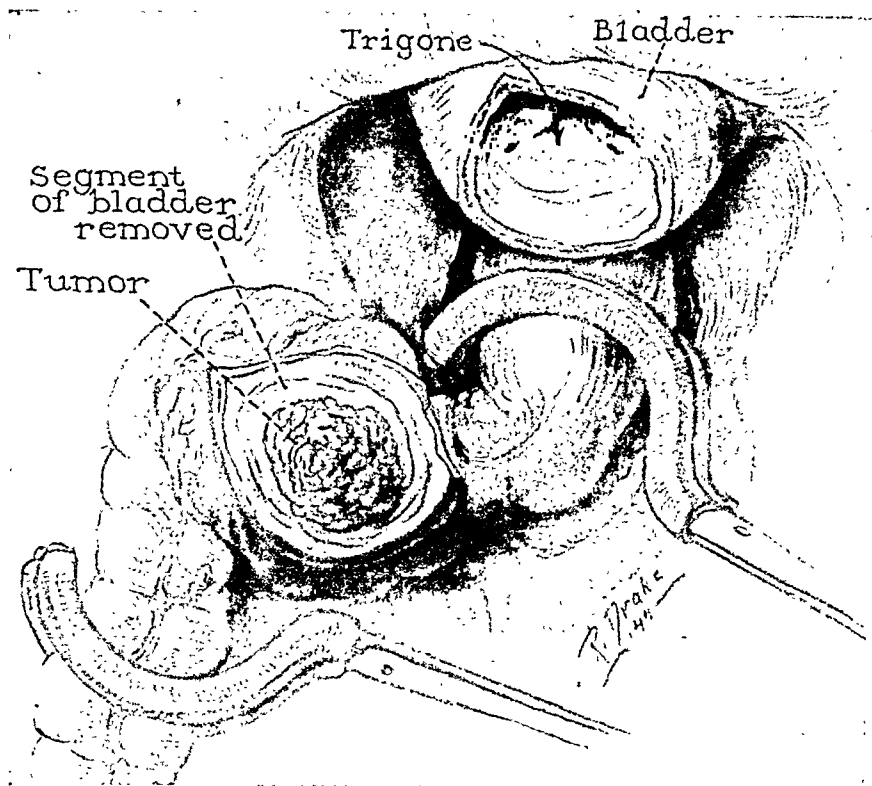


Fig. 2.—The involved portion of vesical wall, including a cuff of normal tissue, has been completely resected. The peritoneum has been incised medially and laterally and the rectosigmoid and upper part of the rectum have been freed from the hollow of the sacrum. The curved clamps indicate the points at which the bowel will be severed after resection of the adjacent mesentery and superior hemorrhoidal vessels.

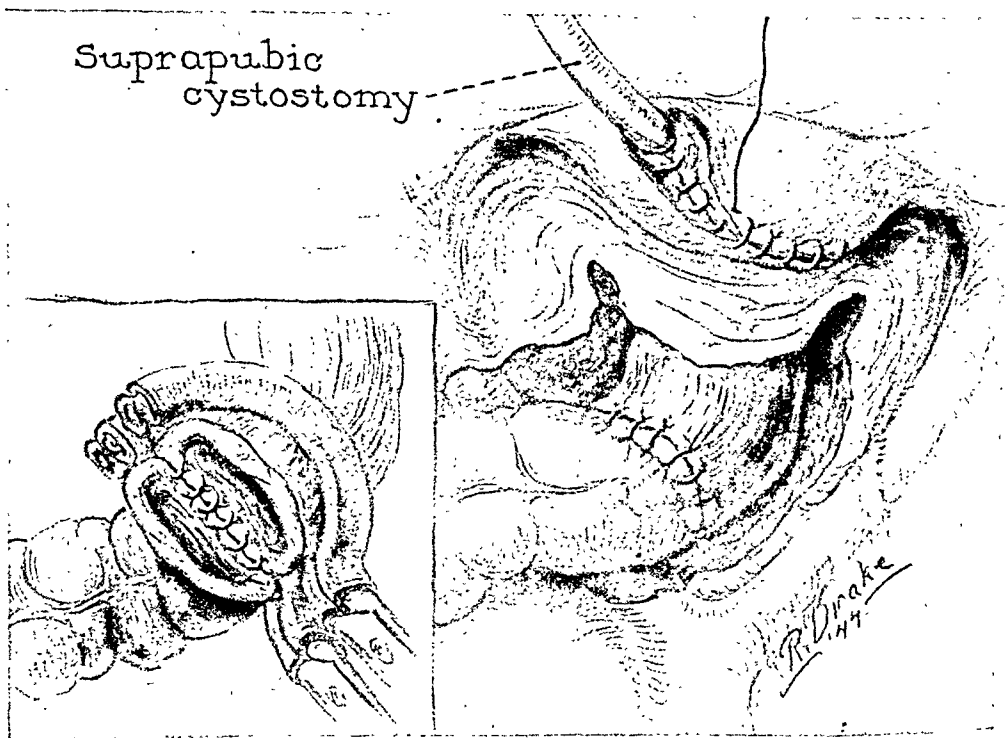


Fig. 3.—Over curved rubber-covered clamps an open type of end-to-end anastomosis is performed. Interrupted sutures which include all layers suffice for the posterior row (inset). The anastomosis then is completed. The urinary bladder is closed around a suprapubic cystostomy tube of large caliber. Following this the pelvic floor will be peritonized in such a manner as to place the colonic anastomosis in a retroperitoneal position.

testine this segment must be defunctionalized for two to three weeks by establishing a loop colostomy proximal to the anastomosis. A segment of transverse colon, brought out through a stab wound in an upper midline position, usually serves the purpose, and requires only a few minutes of operating time (Fig. 4).

Anastomoses low in the pelvic colon have a tendency to "leak." The distal segment is often the upper rectum or the rectosigmoid, which has been mobilized from the hollow of the sacrum and obviously does not have a serosal or peritoneal covering. Therefore, satisfactory anastomosis is dependent on the sutures in the mucosal and muscular layers of the intestinal wall. If a colostomy proximal to the lesion is performed, little or no difficulty is experienced, but if the content of the bowel passes over the site of anastomosis before healing has occurred, pelvic inflammation and inflammatory granulomas in this area sometimes result.

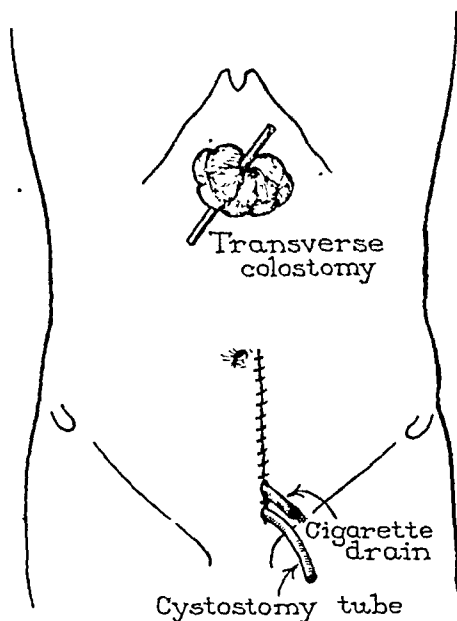


Fig. 4.—Temporary colostomy has been performed by bringing out a loop of transverse colon through an upper midline stab incision. The suprapubic cystostomy tube emerges from the lower angle of the operative incision. Immediately above it is a Penrose drain which extends down to the site of anastomosis in the hollow of the sacrum.

If, after resection, neither of the previously described procedures is applicable, both ends of the bowel can be inverted provided colostomy proximal to the lesion previously was performed (Case 3). If colostomy was not performed previously, a single-barrel colostomy can be provided, the proximal end of the bowel being brought out onto the anterior abdominal wall, and the distal stump can be inverted (Case 4).

After resection of the colon the opening in the bladder is closed snugly around a suprapubic cystostomy tube (Fig. 3). Two layers of running sutures of plain catgut, the first of which is essentially a mucosal layer and the other a serosal or muscular layer, are supplemented by a row of interrupted serosal sutures. When extensive resection of the bladder has been performed it is probably inadvisable to depend on a urethral catheter for drainage of the bladder. Because of the necessarily small caliber of such catheters, they may become plugged and urine may leak into the abdominal cavity through the suture line. This danger is minimized if a suprapubic cystostomy is performed and a 26 or 28 French catheter is inserted. The suprapubic cystostomy tube of large caliber is brought out through the most anterior portion of the bladder incision, through

the space of Retzius, and is sutured into the lower angle of the primary incision (Fig. 4). This tube is easily removed in two or three weeks and the resulting urinary fistula rapidly closes spontaneously.

Resection of the bladder also can be performed in the course of radical posterior resection by cautery (Case 5) or in the course of the combined abdominoperineal operation (Case 6). When the growth is so low in the rectosigmoid that one of these two types of operation is indicated, the involvement of the bladder often is near the trigone and especial care is necessary to avoid injury of vital structures in this region.

REPORTS OF CASES

CASE 1.—A white man, 70 years of age, was operated on for a huge tumor in the lower part of the sigmoid, which had infiltrated into a large portion of the urinary bladder. The sigmoid and a considerable portion of the urinary bladder were removed. Double-barrel colostomy was performed, the cut ends of the colon being exteriorized and held in position on the abdominal wall with a three-bladed clamp. The urinary bladder was closed around a suprapubic cystostomy tube.

The pathologists reported the lesion to be an adenocarcinoma, grade 3 (Broders) and type C.*

Later the colonic stoma was closed. The patient was alive and well five years later.

CASE 2.—A white woman, 47 years of age, had extensive carcinoma of the lower part of the sigmoid. The lesion also involved the uterus and urinary bladder. Preliminary colostomy had been performed elsewhere. The involved portion of bowel, adjacent mesentery, uterus, both fallopian tubes and ovaries, and a large portion of the urinary bladder were removed. Continuity of the bowel was established by end-to-end anastomosis of the middle portion of the sigmoid to the upper part of the rectum. The urinary bladder was closed around a suprapubic cystostomy tube.

The lesion was an adenocarcinoma, grade 2 (Broders) and type C (Dukes), which extended completely through the uterus and also involved the urinary bladder.

Subsequent to resection the colonic stoma was closed. The patient died two years after operation, of abdominal carcinomatosis.

CASE 3.—A white man, 42 years of age, had a large carcinoma of the rectosigmoid which practically filled the true pelvis and involved secondarily the posterior wall of the bladder and the terminal portion of the ileum. Preliminary colostomy was performed in the descending segment of colon. Later the involved portion of the colon, the terminal part of the ileum, and about two-thirds of the urinary bladder were resected. The cut ends of the rectum and sigmoid were inverted. Continuity of the small bowel was obtained by end-to-end anastomosis. The urinary bladder was closed around a suprapubic cystostomy tube.

The pathologist reported the lesion to be grade 2 (Broders) and type C (Dukes) colloid adenocarcinoma.

The patient died on the seventh postoperative day, of generalized peritonitis.

CASE 4.—A white man, 57 years of age, had a large, perforating carcinoma of the middle portion of the sigmoid, which secondarily had involved the terminal part of the ileum and the urinary bladder. The sigmoid, 17 cm. of ileum, and a large portion of the dome and posterior wall of the bladder were resected. Because resections of portions of the ascending colon and of the descending colon had been performed seventeen and seven years previously, respectively, the descending colon could not be mobilized sufficiently to allow its anastomosis with the rectosigmoid at this operation. Accordingly, the end of descending colon was brought out through a stab incision in the abdominal wall to provide a single-barrel colostomy and the rectosigmoid was inverted. Side-to-side ileo-ileostomy restored continuity of the small intestine. The bladder was closed around a suprapubic cystostomy tube.

The lesion proved to be a grade 1 (Broders) and type C (Dukes) colloid adenocarcinoma.

This patient was alive and well six months after operation.

CASE 5.—A white man, 65 years of age, had a large carcinoma of the rectosigmoid and rectum that also involved the urinary bladder and prostate gland. Preliminary sig-

*Dukes, C. E., Classification of Cancer of Rectum, J. Path. & Bact. 35: 323-332, 1932.

moidostomy (loop type) was performed. Three weeks later radical posterior resection of the rectum, rectosigmoid, and lower sigmoid was performed by cautery. The involved portions of the prostate gland and urinary bladder also were removed. The distal end of sigmoid was inverted and replaced in the peritoneal cavity. The opening in the urinary bladder was closed with interrupted sutures of catgut. Drainage of the bladder was provided by use of a urethral catheter.

The pathologists reported the lesion to be a colloid adenocarcinoma, grade 2 (Broders) and type C (Dukes).

This patient was alive and well five years later.

CASE 6.—A white man, 53 years of age, had a large obstructive type of carcinoma of the rectosigmoid which was firmly adherent to the base of the urinary bladder. A combined abdominoperineal resection was performed in two stages. A large portion of the posterior wall and base of the bladder, just above the trigone, was involved. This segment of bladder was resected and the opening was closed through the anterior abdominal incision.

The pathologists reported the lesion to be an adenocarcinoma, grade 2 (Broders) and type C (Dukes).

The patient died on the twenty-second postoperative day from pulmonary embolism and pneumonia.

DISCUSSION

Of the sixty-four patients in the present series, fifty-nine were men and five were women. The apparent infrequency of involvement of the urinary bladder in this condition in women, in comparison with men, is evidently attributable to anatomic differences in the pelvis. In women the uterus, broad ligaments, ovaries, and fallopian tubes are interposed between the urinary bladder and the pelvic colon and thus protect the urinary bladder against invasion by carcinoma originating in this portion of the intestine. In four of the five women in this series the uterus and its appendages also were extensively infiltrated by the disease. In such instances cure is possible only if the involved portions of the uterus and its appendages are removed together with the affected portions of the bladder and colon. The ages of the sixty-four patients varied from 29 to 76 years, the average age being 55 years.

Involvement of the urinary bladder usually does not occur in the early stages of malignant processes of the pelvic colon. It is most commonly a late phenomenon which eventuates only after the tumor has attained a large size and has extended beyond the confines of the intestine. In the majority of cases carcinoma has been present for a long time and it is therefore not surprising that many patients are in poor general condition.

Probably the first step in invasion of the urinary bladder by carcinoma of the sigmoid or rectosigmoid is an inflammatory attachment of the tumor to the peritoneal covering of the bladder. This situation sometimes is encountered at operation. In such a case the malignant process can be dissected from the urinary bladder without making an opening into its lumen. The examination of small bits of tissue from the vesical wall at the site of attachment will reveal the presence or absence of residual carcinoma and will allay any doubt in the surgeon's mind as to whether the malignant process has been completely eradicated. The inflammatory reaction around a secondary malignant growth of the bladder is not only a phenomenon of the early stages but also of the later stages of the malignant disease. Often advanced carcinoma that has extensively infiltrated the wall of the bladder is surrounded by such a severe inflammatory reaction that it is difficult to determine, even at operation when the lesion is in full view and can be examined by the palpating hand, whether the reaction is primarily inflammatory or neoplastic.

When a large carcinoma in the sigmoid or rectosigmoid has extended to the urinary bladder and is surrounded by an indurated inflammatory reaction,

the surgeon may be tempted to perform colostomy and to wait several weeks for the inflammation to subside before undertaking resection of the bowel. Undoubtedly this is often a valuable procedure but the senior author recently has concluded that postponement of resection after the distal segment of colon has been defunctionalized usually will not appreciably diminish the inflammatory reaction if the malignant growth has penetrated completely through the wall of the bladder. In such instances the urine and the diseased condition of the bladder continue to "feed" the infection in spite of the use of urinary antiseptics. Therefore, it has become the senior author's practice to resect such lesions primarily whenever the general condition of the patient warrants the procedure.

In forty-two of the sixty-four cases in this series the condition was classified as operable. Two patients in the group who had presumably removable lesions died after colostomy. In the remaining forty cases, resections were performed. In nineteen of the forty cases the attachment to the bladder was of an inflammatory nature and removal of the tumor did not necessitate an opening into the lumen of the bladder. In the remaining twenty-one cases, portions of the full thickness of the vesical wall were removed. In fifteen of these, approximately one-third or more of the organ was resected; in six cases smaller segments were resected.

In most of the cases resection of the bowel was completed by end-to-end anastomosis. Anterior resection with end-to-end colocolostomy was performed on sixteen of the forty patients who underwent resection. In ten cases the segments of bowel were of sufficient length following resection to permit the ends to be exteriorized. In three cases, loop colostomy proximal to the anastomosis was performed and after resection both ends of the colon were inverted. In four cases the cut end of the distal segment of intestine was inverted, and the proximal end was used in performing single-barrel colostomy. Resection of the bladder was carried out in three cases at the time of combined abdominoperineal resection, and in four cases in conjunction with radical posterior resection by cauterization.

Only palliative operations could be performed in twenty-two of the sixty-four cases. In eight of these twenty-two cases, metastatic growths in the liver, lungs, or other distant organs were present. In seven cases the carcinoma was irremovable because it was extremely large and had infiltrated extensively into the bladder and other pelvic organs. In seven cases the patient was debilitated, anemic, cachectic, and in such poor general condition that resection was considered inadvisable. Roentgen or radium therapy often was employed when removal of the carcinoma was contraindicated because of the poor general condition of the patient.

SURVIVAL RATES

Of the forty patients subjected to radical resection, twenty were still living at the time of inquiry between March and September, 1944, or had survived for five years or longer, as shown in Table I. Of these, seven have lived for more than five years since operation, two for four years, one for three years, two for two years, and five for one year. In three cases the operation was performed less than one year prior to preparation of this report in October, 1944.

The cases in this series in which cures have existed for the longest periods are not limited to those in which early or slight involvement of the urinary bladder was present. Of the ten patients who have survived for three years or longer, seven were classified as having a slight to moderate degree of bladder

infiltration; three had massive involvements necessitating extensive resection of the urinary viscus.

Thirteen patients died after leaving the hospital. The shortest duration of life was two months. Several patients survived for more than two years, however.

Resection of the urinary bladder in the course of radical operations for the cure of carcinoma of the sigmoid or rectosigmoid entails an increased operative risk. Seven of the forty patients who underwent radical resection died in the hospital. Bronchopneumonia was responsible for death in two cases, pulmonary embolus in two, peritonitis in one, liver abscess in one, and intra-abdominal hemorrhage in one.

TABLE I. SURVIVAL AFTER RESECTION IN CASES OF CARCINOMA OF SIGMOID AND RECTOSIGMOID

YEARS	CASES
5 or more	7*
4	2†
3	1†
2	2†
1	5†
Less than 1	3†

*Recent follow-up not attempted in cases in which patients were known to have survived for five years.

†Inquiry made between March and September, 1944.

SUMMARY AND CONCLUSIONS

1. Carcinoma of the sigmoid and rectosigmoid may invade the urinary bladder and other adjacent structures without producing distant metastatic growths. Such lesions are often amenable to resection through the abdominal wall. If this is not feasible, the combined abdominoperineal operation or radical posterior resection can be considered.

2. A small amount of secondary invasion of the urinary bladder by carcinoma of the sigmoid or rectosigmoid may give rise to no clinical or laboratory findings. More extensive involvement often produces distressing urinary symptoms and pyuria.

3. Of sixty-four patients who had carcinoma of the sigmoid or rectosigmoid involving the urinary bladder, forty patients underwent extensive resection. There were seven operative deaths. Twenty of the forty patients are still living, having survived for from less than one to more than five years after operation. Seven have lived for five years or longer.

SUCCINYLSULFATHIAZOLE AND INTESTINAL SUCTION IN SURGERY OF THE LARGE BOWEL

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THERE have been two recent important improvements in the preoperative preparation of patients for large bowel surgery. The first is the use of the Miller-Abbott tube and the second is the use of chemotherapy to minimize the number and virulence of organisms within the lumen of the bowel. This paper is a statistical report of our experience at the Peter Bent Brigham Hospital with these two adjuncts to surgery of the colon. It compares the results in a series of consecutive cases of large bowel resections prepared by these two techniques with a comparable series in which these techniques were not used.

Until recently, proximal colostomy has been widely used in preparing patients for resection of the large bowel. The advantage of preliminary colostomy is that, preoperatively, the bowel is relieved of distention and may regain its function and the distal lumen may be nearly emptied of its contents; postoperatively, the site of anastomosis is kept at rest and the risk of "blowout" at the suture line from increased intraluminal pressure due to temporary obstruction at the anastomosis is minimized.

When the Miller-Abbott tube was introduced,¹ which could apply intraluminal suction drainage to the lower ileum or right colon, Whipple used it to obviate the necessity of preliminary colostomy.² His results were so good that Miller-Abbott tube drainage of the lower ileum was adopted as a routine measure in the preparation for elective large bowel surgery at this clinic and supplanted the routine proximal colostomy.

A special risk of surgery upon the large bowel is infection. Sterilization of the lumen would be the ideal plan for preoperative preparation. Poth and Knotts and associates^{3, 4} introduced succinylsulfathiazole as an agent to reduce greatly the number of large bowel bacteria. They have reported good results when it is used in preparation for large bowel surgery.^{5, 6} Other reports of its successful use have been made by Firor,⁷ Archer and Lehman,⁸ and Behrend.⁹

SELECTION OF CASES

The control group of cases in this study includes patients who had resections of the large bowel between 1938 and 1942. This interval was selected because all the operations are recent enough to be well within the period of modern parenteral therapy and postoperative care. Preliminary colostomy was the routine procedure in this group of cases when the patients were to have primary anastomosis. The test group of cases includes those in which the patients were operated upon since 1942. It differs from the control group only in that all patients were prepared by introduction of the Miller-Abbott tube and the administration of succinylsulfathiazole.

PREOPERATIVE CARE

The patients in the control group were prepared for operation by saline catharsis, enemas, low residue, high vitamin, high caloric diet, and proximal colostomy was performed if a primary anastomosis was contemplated.

Mineral oil by mouth for one day only was given in the test cases. The sulfasuxidine* was then administered after the technique of Poth⁶; 0.5 Gm. per kilogram of body weight was given during the first day, and thereafter 0.25 Gm. per kilogram of body weight during each succeeding day. The drug was given in six equal doses per day and continued for four to twelve days, usually five or six days before operation. The patients were carefully observed for evidences of toxic reactions to sulfathiazole,¹⁰ although none appeared.

Two days before operation the Miller-Abbott tube was introduced. In general the tip passed the pylorus with little difficulty.† Suction was maintained during the passage of the tube. The day before operation, the position of the tube was checked by x-ray. Operation was not undertaken until the end of the tube was in the lower ileum (Fig. 1). During the preoperative period, high vitamin, high caloric, low residue diet was given. Feeding was interrupted only while the tip of the tube was in the stomach.



Fig. 1.—X-ray check shows the tip of the Miller-Abbott tube in the lower ileum, the ideal preoperative position.

During operation, the tube was kept in place. Suction was maintained in the postoperative period until good peristalsis could be heard. Suction was then temporarily discontinued and if distention did not appear and the patient passed flatus and feces, the tube was removed. Usually the tube was left in place until the fifth or sixth postoperative day. If there was doubt whether the tube should be removed, it was left in place for a day or so more.

*N⁴ succinylsulfathiazole is registered under the proprietary name of sulfasuxidine by Sharp and Dohme, Inc., Philadelphia, Pa.

†A technique which seems to have assisted in passing the tip of the tube through the pylorus consists in tying one end of about eighteen inches of plain catgut to the bucket tip of the Miller-Abbott tube. When the tip of the tube is in the stomach, the free end of the catgut passes easily through the pylorus and directs the tip of the tube into the pylorus. The catgut is soon digested in the small bowel and disappears.

OPERATIVE PROCEDURES

The type of resection and anastomosis in the test group was the so-called "closed" type except when ileotransversecolostomy was performed after right colectomy; then the procedure was "open." The technique of resection and end-to-end anastomosis used is illustrated (Fig. 2). It was carried out with fine silk sutures, using two or occasionally one row of interrupted Halsted sutures.

RESULTS

Comparison of all cases of each group shows that when the Miller-Abbott tube and sulfasuxidine were used, there was a reduction in the mortality from

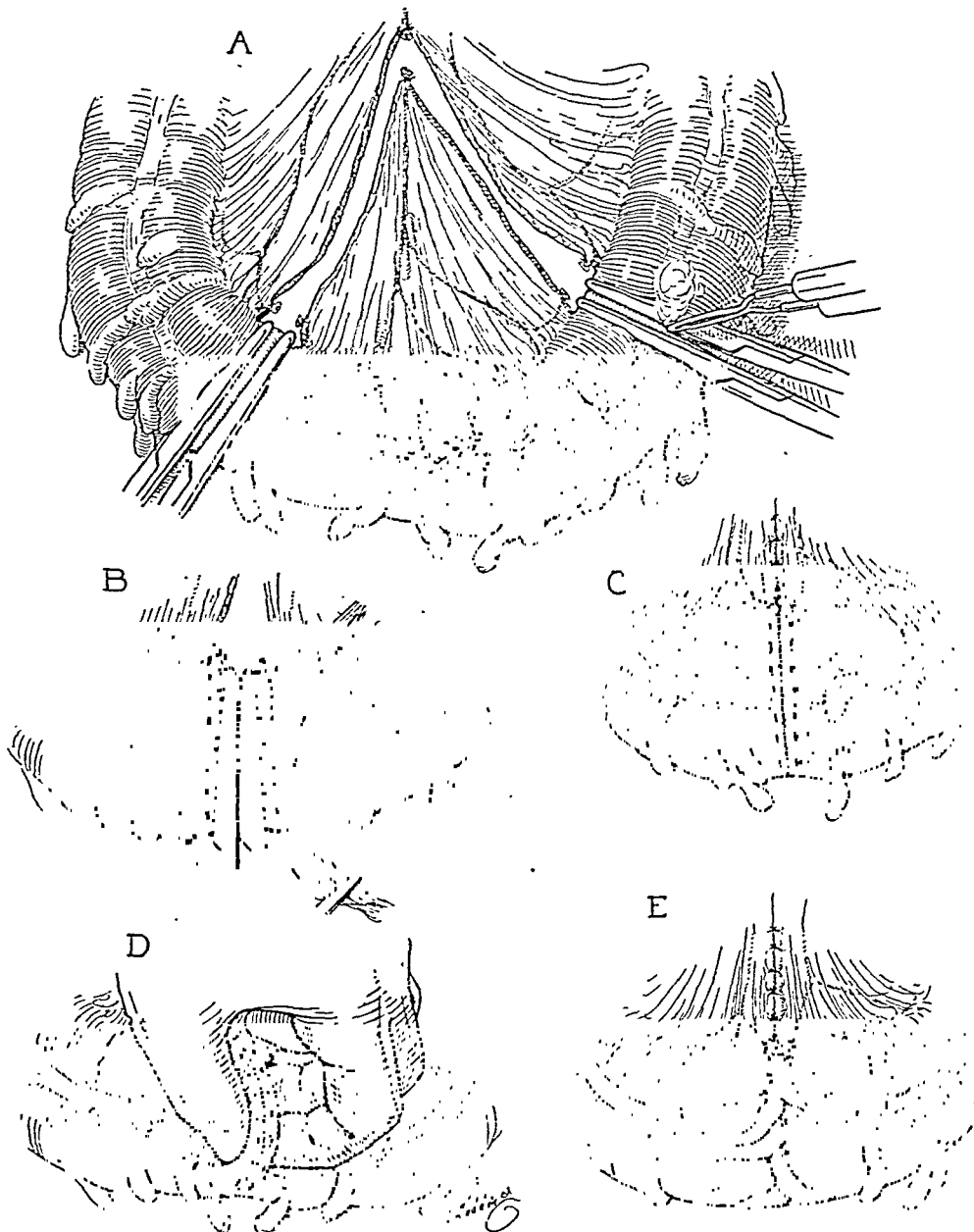


Fig. 2.—A, After the bowel has been prepared for resection, excision is made with the actual cautery. B, Halsted mattress sutures of silk are placed on one side of the bowel and then on the other. C, The clamps are removed and the sutures are drawn up and tied. Extra sutures are placed as necessary or a second row of Halsted stitches may be placed. The mesentery is united with interrupted sutures. D, The diaphragm between the two lumina is broken. E, The fat tabs are sutured over the anastomosis.

19 to 3 per cent and a reduction in the number of patients with complications from 58 to 25 per cent (see Table I).

TABLE I. COMPARISON BY CASES OF RESULTS IN LARGE BOWEL SURGERY

	NUMBER OF CASES	CASES WITH COMPLICATIONS		DEATHS	
		NO.	PER CENT	NO.	PER CENT
Control group (Miller-Abbott tube and sulfasuxidine not used)	78	45	58	15	19
Test group (Miller-Abbott tube and sulfasuxidine used)	36	9	25	1	3

A more significant comparison may be made if cases with similar operative procedures are compared and if the complications are separated into those occurring locally at the site of operation, and those occurring to the patient in general. In Tables II and III are presented the cases of the control and

TABLE II. CASES OF CONTROL GROUP ANALYZED FOR OPERATIVE PROCEDURE AND TYPE OF COMPLICATIONS

	NO. OF CASES	CASES WITH LOCAL COMPLICATIONS				CASES WITH GENERAL COMPLICATIONS						DEATHS	
		INFEC- TION		DISRUP- TION		PUL- MONARY		PHLEBI- TIS		MISC.			
		NO.	PER CENT	NO.	PER CENT	NO.	PER CENT	NO.	PER CENT	NO.	PER CENT	NO.	PER CENT
Resections with anas- tomoses	37	16	43	0		5	13	0		1		8†	22
Mikulicz resections	27	7	26	4	15	4	15	0		0		5‡	19
Anterior resections of rectosigmoid*	8	4	50	0		0		2		2		0	
Resections of rectum	6	5	83	0		1		0		1		2§	33
Total	78	32	41	4	5	10	13	2	3	4	5	15	19

*An "anterior resection" removes a segment of rectosigmoid and leaves an end colostomy and an inverted segment of rectum.

†Five patients died of peritonitis; two, of pelvic abscesses and pneumonia; one, of aortic stenosis.

‡Two patients died of peritonitis; one, of septicemia; one, of bronchopneumonia; one, of pulmonary edema.

§One patient died of peritonitis; the other died of pulmonary embolism. Both of them had undergone first stage resections.

test groups divided by type of operative procedure and classifying the complications. The local complications are subdivided into those resulting from infection and from wound disruption. General complications are subdivided into pulmonary complications, phlebitis, and miscellaneous complications. If a single patient had both a local complication and a general complication, each is recorded. In Fig. 3 are compared the results in the strictly comparable groups of cases found in Tables II and III. It demonstrates a statistically

TABLE III. CASES OF TEST GROUP ANALYZED FOR OPERATIVE PROCEDURE AND TYPE OF COMPLICATIONS

	NO. OF CASES	CASES WITH LOCAL COMPLICATIONS				CASES WITH GENERAL COMPLICATIONS								DEATHS	
		INFECTION		DISRUPTION		PULMONARY		PHLEBITIS		MISCELLANEOUS					
		NO.	PER CENT	NO.	PER CENT	NO.	PER CENT	NO.	PER CENT	NO.	PER CENT	NO.	PER CENT		
Resections with anastomoses	32	2	6	3	9	4	13	3	9	0	0	1*	3		
Resections of rectum	4	0	0	0	0	1	25	0	0	0	0	0	0		
Total	36	2	6	3	8	5	14	3	8	0	0	1	3		

*This patient died of massive pulmonary embolism three days after bilateral femoral vein ligation and on the nineteenth day after second stage, right colectomy; a primary ileo-transversecolostomy had been done two weeks prior to the colectomy.

TABLE IV. DISTRIBUTION OF COMPLICATIONS IN CONTROL GROUP*

	LOCAL COMPLICATIONS						GENERAL COMPLICATIONS				
	WOUND INFECTION	ABSCESS INTRAPERITONEUM	PERITONITIS	WOUND DISRUPTION	MISCELLANEOUS		ATELECTASIS	PNEUMONIA	INFARCT	MASSIVE PULMONARY EMBOLUS	PHLEBITIS MISCELLANEOUS
Resections and anastomoses	P-9 S-4	P-1 S-1	P-6	0	0		P-2	P-2	P-1	0	P-1 (death due to aortic stenosis) 0
Mikulicz resections	P-4 S-2	0	P-3	P-4	P-1 (gangrene proximal loop)		P-1	P-3	0	0	0
Anterior resections of rectosigmoid	P-1	P-3	0	0	0		0	0	S-1	0	P-2 (two cases cystitis) P-1 (bacteremia)
Resections of rectum	P-4 S-1	S-1	P-1	0	0		0	P-1	0	0	0

*If a patient had two local or two general complications both are recorded, the more important as primary "P" and the less important as secondary "S."

TABLE V. DISTRIBUTION OF COMPLICATIONS IN TEST GROUP*

	LOCAL COMPLICATIONS						GENERAL COMPLICATIONS				
	WOUND INFECTION	ABSCESS INTRAPERITONEUM	PERITONITIS	WOUND DISRUPTION	MISCELLANEOUS		ATELECTASIS	PNEUMONIA	INFARCT	MASSIVE PULMONARY EMBOLUS	PHLEBITIS MISCELLANEOUS
Resections and anastomoses	P-2	0	0	P-3	0		P-4	0	0	0	P-2 0
Resections of rectum	0	0	0	0	0		P-1	0	0	0	S-1 0

*If a patient had two local or two general complications both are recorded, the more important as primary "P" and the less important as secondary "S."

significant* reduction in complications due to local infection from 43 to 6 per cent, and the statistically significant reduction in mortality from 22 to 3 per cent. It is apparent that the decrease in infection is greater than the decrease in mortality. This effect would be expected because factors may enter into the mortality rate which are not affected by either intestinal suction or sulfasuxidine. Tables IV and V present a further analysis of the data in Tables III and IV.

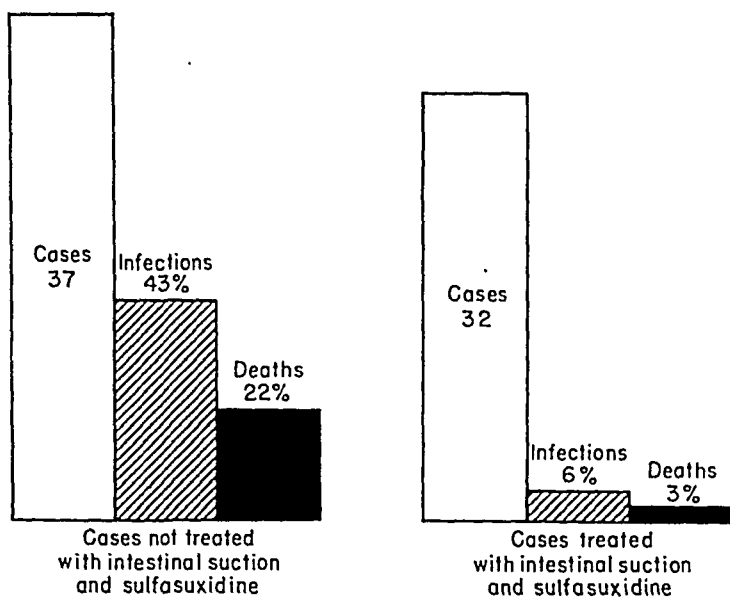


Fig. 3.—Results in large bowel resections and anastomoses with and without intestinal suction and sulfasuxidine.

The apparent increase in wound disruption in the test series of cases cannot be shown to be of statistical significance. It is probably apparent because in the control group of cases those patients who were in a poor nutritional state were chosen for Mikulicz procedures rather than resection and primary anastomosis. Table II shows a higher incidence of wound disruption in the Mikulicz resection group.

The apparent increase in the complication of phlebitis is also not enough to be of statistical significance, even though the frequency of the diagnosis has increased in the last two years because of the greater emphasis on searching for the symptoms and signs of early phlebitis.

DISCUSSION

It appears that the use of succinylsulfathiazole and intestinal suction is a significant contribution to surgery of the colon. Intestinal suction spares the patient the risk of colostomy and colostomy closure; and the succinylsulfathiazole makes the major operative procedure safer, primarily because it produces such marked reduction in the incidence of postoperative local infection. However, we wish here to state our agreement with the opinion of many others that the

*In comparing the percentage change in any two comparable series of cases, the percentage differences must be greater than twice the "standard error of the difference" if the percentage change is to be of statistical significance. The standard error of the difference (S.E.D.) is derived from a formula which takes into account the percentages involved and the number of cases in each group. The change in infection rate above is 4 times the S.E.D. and the change in mortality rate is 2.5 times the S.E.D.

$$\text{S.E.D.} = \sqrt{\frac{\text{Percentage A} \times (100 - \text{Percentage A})}{\text{No. of Cases in Series A}}} \text{ plus } \frac{\text{Percentage B} \times (100 - \text{Percentage B})}{\text{No. of Cases in Series B}}$$

primary requirement in surgery of the colon is a gentle, accurate, and dependable surgical technique. Without this, no adjuncts to surgery can be of any real value.

CONCLUSIONS

A series of 114 cases of large bowel resections was studied. The general preoperative and postoperative care was the same in all except that in the test group (thirty-six cases) preoperative succinylsulfathiazole and preoperative and postoperative intestinal suction were used. In the control group (seventy-eight cases) primary colostomy without chemotherapy was the routine in resections with restoration of continuity.

The Mikuliez type of resection was not required in any cases of the test group.

The following data are of statistical significance in the comparison of the two groups.

1. The gross incidence of complications was reduced from 58 to 25 per cent.
2. The gross mortality was reduced from 19 to 3 per cent.
3. When similar operative procedures (resections and anastomoses) are compared, it is found that the incidence of postoperative infection is reduced from 43 to 6 per cent and the mortality is reduced from 22 to 3 per cent.

The use of intestinal suction and succinylsulfathiazole in the preoperative and postoperative care of patients who undergo large bowel resections has a definite effect in reducing the incidence of postoperative infection and mortality.

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THE TREATMENT OF ADVANCED AND INOPERABLE CANCER

A RÉSUMÉ OF CURRENT TRENDS BASED ON A REVIEW OF THE
LITERATURE AND ANALYSIS OF PERSONAL CASE EXPERIENCES

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INTRODUCTION

THE attitude of the medical profession, as well as the general public, concerning the efficacy of cancer therapy has been one of disheartening pessimism. Numerous reports of five- and ten-year cures in many malignant growths have recently moderated this tendency. Knowledge of similar remarkable advances achieved in the palliative management of advanced and inoperable cancer is insufficiently well known. Chronic diseases, such as hypertension, nephritis, diabetes, thromboangiitis, rheumatic endocarditis, and coronary sclerosis, all likewise incurable, are accepted with relative equanimity by both patient and physician. Therapy in conjunction with skillful implantation of a cheerful outlook toward their illness has supplanted the dread abandonment which was the lot of these victims only two and three decades ago. Equivalent results with respect to patient comfort and longevity in the therapeutics of many incurable neoplasms warrant adoption of a more optimistic approach. The terminal stages of cardiac and renal disease are no less difficult to face than those of cancer, yet to relegate all patients with early cardiac and nephritic illness to the category of irreclaimables when prolonged intervals of comfortable and fairly active existence can be achieved would exactly parallel what is too often offered the cancer patient at an analogous stage.⁵³

In cancer salvage therapy much can be accomplished by radiological and surgical methods. The patient can be promised a minimum of disability and in a certain small minority, treatment may result in cure. Resurgence of interest in this often neglected field is resulting in the accumulation of a large body of data which when given critical statistical evaluation should lead to improved end results. Until research provides cancer controls of established certainty, it is the responsibility of the doctor to utilize present-day knowledge in this province of cancer to the fullest.

SCOPE OF THE PROBLEM

This paper is concerned primarily with the care of the patient with advanced cancer, inoperable at least in the sense that definite possibility of cure cannot be assured. Radical extirpative surgery and radiation have resulted in improved curative results, here briefly mentioned, of cancer of the breast, colon, rectum, skin, uterus, stomach, kidney, and larynx and to a lesser degree in cancer of the lung, esophagus, and bladder.^{25, 50, 52} The progressive role of public health education in minimizing factors producing unnecessary delay in the treatment of cancer is likewise beyond the immediate scope of this paper.

Roughly less than 15 to 20 per cent of all patients with malignant lesions ultimately achieve the status of "five-year cure."^{29, 49} Epitheliomas of the

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head, neck, bladder, and cervix and less frequently carcinomas of the esophagus, colon, rectum, prostate, and breast by virtue of their relatively early symptomatology may present themselves at a stage where cure is possible. The majority of other malignancies are not as often recognized at an early enough stage so that cure can be expected.^{11, 15, 44, 45, 50} It can be estimated then that 80 per cent of all cancer patients, excluding small epitheliomas, will either primarily or secondarily require palliative medical care.^{20, 49, 61} Since in any given year there are approximately one-half million cancer patients in the United States,²² some 400,000 individuals are prospective candidates for such treatment. Viewed in this light the problem is one of major significance and the potential extension of life and comfort is tremendous.

THE STATUS AND CLASSIFICATION OF THE PATIENT WITH ADVANCED AND INOPERABLE CANCER

In addition to the local, regional, and distant spread of the primary neoplasms, two other major factors influence the curability of the lesion: (1) concomitant illness and (2) physical infirmities of advanced age. It must be emphasized, however, that advanced age of itself does not exclude the application of radical curative or palliative procedures in the relatively vigorous patient. Given proper preparation and follow-up care, the elderly may tolerate such therapy admirably.^{1, 59, 68} Infection not only serves as a further toxifying agent but it also appears to stimulate the active spread of the neoplasm.

A working classification into groups of the more usual advanced cancer cases is of importance in bringing into focus the dominant problems encountered and the symptoms to be ameliorated.⁶¹

I. Head and Neck Group.—The head and neck group consists predominantly of epitheliomas and constitutes some 17 per cent of all malignancies.^{2, 3, 15} Since even the uncontrollable cases in this division are apt to be slow-growing, proper palliation has much to offer. Frequently growth progresses regionally, often resulting in large open ulcerations and hemorrhage; osteomyelitis of underlying bone; destruction of oropharyngeal structures with dysphagia; or involvement of the larynx, often by massive enlargement of cervical lymphatics, with resultant dyspnea.^{2, 3, 8} Carcinoma of the esophagus, characterized primarily by dysphagia, is also considered here. The relatively few tumors in this area which metastasize generally present essentially the features to be described here.

II. Abdominothoracic Group.—The abdominothoracic group is best considered under several subheadings grouped according to their disseminative tendencies. Treatment of their symptoms require similar palliative procedures despite the widely varying natures of the primary neoplasm.^{40, 43, 61, 69, 73, 74}

A. Generalizing cancers: The majority of advanced cancers of the breast, lung, kidney, prostate, and ovary, constitutes almost 30 per cent of all cancers. They tend to metastasize to the osseous systems, lungs and pleura, liver and peritoneum, kidney and adrenals, and brain in roughly that order.^{23, 40, 43, 69, 73, 74} In some 15 per cent of cases metastases, for some little understood reason, appear clinically limited to the bones for a prolonged interval.^{6, 21, 27, 73} Here pain in the spine, pelvis, and extremities, or of a radicular nature, and pathologic fractures are our main concern. Hepatic, pulmonary, adrenal, and uncommonly renal insufficiency, singly or in combination, may ensue, secondary to parenchymal replacement by tumor tissue.⁶⁹ Surprisingly, patients with known lung and liver involvement may maintain active and useful existences

for periods up to two to three years, rarely longer. Advanced intracranial involvement dictates that measures be limited to securing maximum relief of pain and rest. This is also true in the terminal phases of massive liver, peritoneal, lung, and pleural infiltration. Ascites and pleural effusion, however, may ensue long before the patient's condition warrants discontinuance of supportive measures. Jaundice in this group fortunately comes late, as a rule, since it is usually the result of periportal invasion. Cancers of the breast frequently present the specific problem of lymphedema and infiltration of the chest wall, axillary and supraclavicular glands, brachial plexus, and subclavian vessels.^{27, 31, 55} Metastases to any sensory nerves may result in agonizing and long-continued pain.

B. Intermediate cancers: Over 30 per cent of malignancies are included in the group of intermediate cancers. Carcinoma of the stomach, colon, and rectum often generalizes late and in somewhat different fashion. Hepatic and pulmonary involvement are apt to be less massive, except for anaplastic gastric cancers.^{43, 60} Extension to surgically inaccessible regional lymphatics may be the only factor interdicting curability. Instances of isolated enterostomy site recurrences occur sufficiently frequently to be given special consideration. Cancer of the pancreas may produce distressing jaundice by compression or, more commonly, by invasion of the common bile duct. Retroperitoneal extension productive of nerve root pain may be encountered early in gastric and pancreatic malignancy.^{37, 71} Malnutrition, nausea, vomiting, intestinal obstruction, diarrhea, and tenesmus may all develop at a stage where their relief may provide a protracted interval of comfort and even activity for the sufferer. These lesions tend to widespread invasion of the parietal and visceral peritoneum, which results in multiple and intractable intestinal obstruction.^{40, 69, 74}

C. Localizing cancer: Cancers of the uterus, cervix, bladder, and external genitals comprise approximately 18 per cent of cancer cases, the great majority of which are pelvic epitheliomas. Extension occurs relatively late and is often limited to local invasion and spread to the regional lymphatics. The major factors operating against curability here are inaccessibility of involved pelvic fascial planes and deep-seated pelvoinguinal lymphatic structures; also there is a tendency to conglomerate involvement of pelvic organs or so-called "frozen pelvis." Cancer of the cervix and bladder often spreads in such fashion as to occlude the ureters, leading to hydronephrosis and pyelonephritis, which if unchecked will result in uremia. The less anaplastic prostatic lesions often take this same course. Vesicorectal, rectovaginal, and vesicovaginal fistulas may be the distressing end result. On occasion urinary retention may occur, although an agonizing frequency is the more common complaint. At times rectal involvement may cause either tenesmus or obstructive symptoms. Massive hemorrhage may occur in cervical and less frequently in rectal lesions.⁶⁹

III. Sarcomas.—Melanosarcomas, osteogenic and unspecified sarcomas, and lymphoblastomas in the aggregate come to but 5 per cent of all malignancies. Advanced cases present most often mediastinal, pulmonary, and hepatic metastases, bulky invasion of inguinal para-aortic, or cervical lymphatics, and on occasion a ponderous ulcerated infected primary focus. Terminal cases, often present a dissemination as generalized as that of cancer of the breast.⁴³

PROBLEMS OF TREATMENT IN ADVANCED CANCER

By now reviewing briefly the pathology of ineradicable cancer, the symptoms requiring palliation become clarified. Therapeutic programs can be facil-

tated by the schematic presentation of the most common problems for which worthwhile remedial measures can be carried out.

I. *Head and Neck Group*.—Intractable dysphagia and dyspnea, extensive ulcerations or fungating lesions associated with hemorrhage, osteomyelitis and radiation necrosis, osteochondritis, massive cervical lymphadenopathy, pain mediated by trigeminal and upper cervical nerves, malnutrition.

II. *Abdominothoracic group*.—

A. *Generalized metastases*:

- (1) Osseous: Pain in skull, spine, pelvis, extremities. Pathologic fractures, most commonly of humerus, femoral shaft and neck, thoracolumbar spine and pelvis.
- (2) Lung and Pleura: Pain, cervical and thoracic, innervated by cervical trunks, intercostal and phrenic nerves. Pulmonary insufficiency due to lung replacement or atelectasis; pleural effusion.
- (3) Peritoneum, Liver, and Adrenals: Frequently leading to hepatic and suprarenal insufficiency. Massive ascites; abdominal pain mediated by autonomic nervous system and lower thoracic nerves. Malnutrition, nausea, vomiting, diarrhea, and obstipation.
- (4) Somatic and Peripheral Nerve Infiltration: Brachial plexus and upper intercostal nerve pain in cancer of breast and pulmonary apices. Thoracolumbar spinal nerve root pain in primary or secondary retroperitoneal growths. Lymphedema and infiltration of chest wall, axillary, and supraclavicular glands, primarily in malignancies of mammary origin.

B. *Localized metastases*:

- (1) Abdominal: Large fungating lesions of gastric wall, cecum, and colon causing obstructive symptoms, diarrhea, or interference with nutritive absorption; recurrences about enterostomy or enteroenterostomy stomas. Jaundice due to compression or invasion of ductus choledochus, most commonly in cancer of head of pancreas.
- (2) Pelvic: Pain along autonomic and lumbosacral nerves. Rectosigmoid obstruction. Rectal, vesical, and vaginal fistulas. Tenesmus and urinary urgency. Hemorrhage. Ureteral obstruction, pyelonephritis, and uremia.
- (3) Extremities: Elephantiasis of extremities with bulky, ulcerating, infected bone-invading primary tumors, associated with regional lymphadenopathy. Pain along peripheral nerves of extremities.

METHODS OF TREATMENT OF ADVANCED AND INOPERABLE CANCER

Radiation Therapy.—Limitation of growth, diminution in size, control of secondary infection, and on occasion total ablation of the primary lesion or of individual metastases are the major objectives of roentgen therapy. In such tumors as the lymphoblastomas, Ewing's myeloma, and epitheliomas of the skin, pharynx, or cervix, radio-sensitivity or accessibility of the primary or secondary lesion contributes to often dramatic results.^{15, 52, 56} Local and lymphatic recurrences of breast cancer may frequently respond to intensive radiation.^{7, 27, 31, 55} The interstitial use of radium or radon in squamous-cell carci-

noma, rectal and bladder malignancies, or the secondary deposits of mammary cancer may be rewarded by arrest or destruction of the lesion. Radiation therapy of laryngeal,¹⁷ esophageal,⁶² bronchogenic,⁴⁶ and gastric⁵⁸ cancer has been productive of significant palliation. Advanced secondary cervical lymphadenopathy^{3, 66} and the frozen pelvis may be benefited to some degree by x-ray treatment. The technical details of radiation therapy cannot be described here, but adequate tumor lethal doses whether by massive or fractional application must be administered.³⁵ Supervoltage apparatus does not appear to offer increased advantage thus far.^{30, 70} Contact therapy, however, has proved itself valuable in dealing with numerous surface lesions, for example in attacking multiple subcutaneous breast cancer metastases.³¹ Recent studies have indicated the palliative value of the oral or parenteral administration of radioactive phosphorus in lymphosarcoma and in some cases of chronic myelogenous leukemia and multiple myeloma.⁴¹ Considerable promise for improved results with x-ray and radium treatment seems definite as research in this field progresses.

Bone metastases, particularly secondary to carcinoma of the breast,³¹ often respond to radiation in spectacular fashion, allowing even three- to five-year periods of active relatively pain-free survival.^{6, 21, 42} Rarefying osteoclastic lesions are replaced by a calcifying or sclerosing osteoblastic process restoring osseous strength and stability. Pathologic fractures may heal sufficiently to permit normal gait and weight-bearing. Treatment of the latter may be usefully augmented by traction, frames, braces, or cast application, and in selected cases by the use of bone pins and plates for fixation. The radiation sensitivity of osseous metastases varies, but does not appear to correspond exactly with that of the primary growth.⁵⁶ Carcinoma of the breast, testes, and thyroid is relatively quite radiation-resistant as a primary lesion, but radiation-sensitive as a secondary skeletal deposit.⁵⁶ Metastatic cancers of the prostate, bladder, cervix, oropharynx, lung, and intestine, on the other hand, generally respond less satisfactorily.²¹ Hypernephroma produces bone secondaries that are quite insensitive to x-rays.³³ Lymphoblastomatous, leucemic, and myelomatous infiltration of bone is frequently greatly relieved by irradiation, particularly in the initial courses of therapy. Isolated pulmonary, pleural, and mediastinal metastases of the more radiation-sensitive tumor types have been known to recede with therapy.⁷⁰ Lastly, the ascites due to peritoneal implantation by ovarian carcinoma may respond favorably.²¹ Here the fluid is not resorbed but the interval between tapings is often prolonged.

Surgery.—Ligation of the carotid arteries for the control of hemorrhage from advanced head and neck lesions is a commonplace procedure. This may permit further therapy of the primary tumor. Resection of involved and necrotic facial bones or mandibles has been followed by as much as several years of relatively comfortable activity in some previously desperate cases.⁸ Since the operation is attended by a relatively low mortality and the tumor is often of a slow-growing type, block dissection of cancerous cervical lymph glands may have much to offer the patient in selected cases.^{3, 24, 66} Many surgeons advocate the excision, by scalpel or electrosurgery, of most large ulcerating or fungating primary or secondary lesions and have demonstrated that a relatively clean granulating surface, in some instances suitable for skin grafting, contributes much to patient comfort and is attended by less pain.^{13, 14, 40, 57, 75} Marked reduction of great and hitherto impenetrable tumor bulk, as of face¹⁴ or breast,⁶⁰ may render irradiation more effective. Electro-

coagulation of large rectal and bladder lesions may give similar temporary improvement.^{5, 75} Denuded raw surfaces kept clean and granulating under pliofilm or paraffin gauze dressings are tolerated better than advanced infected ulcerative lesions.

During exploratory laparotomy the practice of resecting primary gastric or large bowel lesions, when feasible, in the presence of early hepatic involvement postpones the advent of discomfort considerably, as a rule. Case reports of actual resection of isolated hepatic and other intra-abdominal secondary implantations with good results are becoming less great rarities.

Circumventing operations for the relief of dysphagia and obstructive dyspnea may establish temporary rehabilitation of the patient. Low tracheotomy in laryngeal and hypopharyngeal cancer or for massive cervical metastases may facilitate palliative radiation therapy as well as contribute greatly to the comfort of the patient. Tubovalvular gastrostomy may counteract for many months or longer the dysphagia of oropharyngeal cancer or the obstruction of esophageal neoplasms. In large indolent gastric cancers, jejunostomy for feeding purposes may be of some avail. These procedures should not be deferred until the emaciated condition of the patient prejudices the outcome of the operation.

Massive pleural effusion and ascites should be tapped as frequently as the dyspnea and distention are produced. Instances of survival for several years with multiple abdominal or thoracic paracentesis is known. The use of mercurial diuretic, for example, salyrgan or mercupurin, has never lessened the need for puncture⁶⁷ in our experience.

Colostomy, when indicated as palliative procedure for the relief of such symptoms as obstruction by neoplasm, diarrhea, tenesmus, or rectovesical or rectovaginal fistulas, is preferably carried out as a defunctionalizing procedure, completely isolating the lower colonic segment. This allows further surgical, electrosurgical, or radiological attack upon the primary lesion as well as minimizes distress. At times short-circuiting operations, notably ileotransversostomy, for unresectable intestinal obstructive new growths may be resorted to. Tumor recurrences about the colostomy stomas, along with their areas of regional lymphatic spread, are occasionally secondarily resected with good results. Jaundice in carcinoma of the bile duct and pancreas is at times effectively palliated by choledochojejunostomy. Cystoscopic ureteral dilation and drainage, frequently repeated, is occasionally followed by intervals of well-being in pyelonephritis secondary to cancer of the cervix. Ureterostomy, preferably by implantation into the colon, and suprapubic cystotomy may do much to alleviate the suffering of patients with cancer of the cervix, bladder, and prostate.

A hitherto greatly neglected palliative application of surgery, which has only recently come into its own and has been given impetus by the increasing life span afforded certain categories of incurable cancer patients with newer forms of treatment, is the operative relief of pain.^{9, 10, 16} Section or anesthetic infiltration of individual branches of the trigeminal nerve or alcohol injection of the gasserian ganglion are particularly effective and simple procedures too often neglected in advanced face lesions. Glossopharyngeal and cervical alcohol nerve block have a more limited but nonetheless definite field of usefulness. Intramedullary tractotomy has recently been reported for the relief of unilateral face and neck pain in these cases.^{71, 72}

Interruption of sympathetic fibers for the control of intractable pain from various abdominal organs has repeatedly proved its worth. Thus, paraverte-

bral alcohol infiltration to destroy the right lower six thoracic sympathetic ganglia and rami can often give satisfactory relief for the duration of their lives to patients with advanced metastatic carcinoma of the liver.^{37, 72}

Although all uncomfortable sensations may not be obviated by this approach which is calculated to block the newly charted visceral afferent pathways, paravertebral sympathetic block of several segments of the thoracolumbar chain below the level of the sixth thoracic may provide a prolonged and welcome respite from the greater part of pain arising from inoperable cancer of the stomach and intestines. In selected patients splanchnicectomy and thoracolumbar sympathetic ganglionectomy may be attempted. Removal of the upper lumbar ganglia is of value in pain of renal and ureteral origin. Presacral neurectomy³⁶ by interrupting the sacral parasympathetic nerves ameliorates greatly the pain of rectal or bladder neoplasms. Where pain is due to a retroperitoneal invasive process, posterior rhizotomy or spinothalamic tractotomy, that is, anterolateral chordotomy successfully alleviates suffering.^{71, 72} The intrathecal administration of alcohol particularly where lesions are widespread, negating a segmental approach for nerve impulse interruption, can often be depended upon to control pain for several weeks or months by its degenerative action on the posterior rootlets when the proper technique is followed.⁷³ Post-mortem examination has several times confirmed the relatively selective localization of the action of alcohol so introduced into the spinal column to the dorsal sensory nerve roots.⁵¹ In the event of the initial failure of alcohol, or as more recently advocated ammonium sulfate solution,³⁷ administered intraspinally, it may be repeated or neurosurgery may be carried out. Some degree of bladder and bowel incontinence may follow these injections, but to a large extent this is transitory. On occasion a reactive alcoholic neuritis may ensue, in which case pain can be ameliorated by return to the analgesic and narcotic medications previously depended upon. Accurate neurologic localization of the pain zones and pathways prior to instituting these forms of therapy is rewarded by maximum benefits with minimal interruptive techniques.^{37, 72} Stimulated by its use in the edema of thrombophlebitis, cervicothoracic sympathetic block together with elastic adhesive bandaging has given favorable results in several of our cases of lymphedema of the upper extremity following radical mastectomy, and sympathectomy may be advisable.

Formidable surgical procedures in patients with incurable malignant growths have the sole object of mitigating or forestalling unbearable agony where the sufferer can, in the event of survival, look forward to a period of months or years free from pain. Operative death rates of as high as 10 per cent, the maximum generally to be anticipated from the procedures detailed, are not as deterrent as in elective general surgery, since where extreme and prolonged suffering cannot be palliated, a surgical mortality cannot be construed as the same unwelcome outcome. However, the once enormous risks entailed in operating on patients with advanced cancer can be greatly curtailed by thoroughgoing preoperative and postoperative care.^{12, 34, 38, 59}

Surgical sterilization by ovariectomy and orchietomy has had many recent favorable reports in advanced mammary and prostatic cancer, respectively.^{4, 32, 47, 51, 65} Most workers stress the production of temporary clinical arrests and the apparent augmentation of irradiation effects on secondary skeletal lesions. Radiation castration in conjunction with hormonal therapy²⁶ may prove to be effective in the light of current studies. Sporadic instances of five-year apparent cures in patients with bone metastases treated by castration and irradiation supplemented by endocrine administration have been seen.

Pharmacologic Therapy.—Foremost in importance among the medications given in advanced cancer are the analgesics. A cardinal principle to be followed in their administration is the postponement of narcotic utilization until the decreased potency of other drugs counterweighs the disadvantages of potential addiction. At the outset salicylates and barbiturates are generally adequate, later to be supplemented by codeine, which rarely causes serious habituation. Small doses of morphine, pantopon, or dilaudid may prove effective for long periods in the majority of cases. Whenever possible, relief of intractable regional pain by alcohol nerve block or neurosurgery is preferred to the deleterious effects of constant dependence on large doses of narcotics. On the other hand, since the comfort of the patient is of paramount importance, opium derivatives or analogues and sedatives should not be withheld when other measures are no longer of avail. Recently demerol⁶⁶ has been found to induce satisfactory pain relief, in some instances, without many of the well-known physiologic disadvantages of the opiates. For oropharyngeal lesions, local anesthetics, such as orthoform or cocaine are helpful. Numerous medicaments have been sponsored as panaceas for the pain of advanced malignancies, the majority of which are the subjects of conflicting descriptions concerning their usefulness. Cobra venom falls into this class of substances which cannot be said to offer uniform palliation. Other preparations which have had considerable vogue but seemingly fail in the majority of cases are colloidal lead and gold solutions and Coley toxin.⁶⁷ Recent trial of H 11 and heptaldehyde has been relatively fruitless.

The need of supportive measures in the treatment of progressive malignancy should never be overlooked. Malnutrition, dehydration, disturbance of acid-base equilibrium, and cachexia may be combated by oral, tubal, and parenteral administration of nutritive fluids and electrolyte solutions. Care must be taken to guard against overloading the circulation in the frequently concomitant cardiovascular degenerative diseases.^{12, 50} Specific metabolic deficiencies leading to anemia and hypoproteinemia seem to characterize many forms of cancer.⁵⁹ High caloric diets, protein hydrolysates, liver concentrates, and hematinics are thus of great value, and serve to lessen weakness, fatigability, and susceptibility to infection. Similarly indicated are various poly-vitamin preparations, since avitaminosis of various types is generally encountered in these patients and anorexia is commonplace. The vitamins may serve to control nausea and vomiting. Sedation judiciously administered in conjunction with antispasmodics and alkali carminative powders may also help. In gastric carcinoma with attendant achlorhydria, dilute hydrochloric acid and pepsin may be beneficial. Gastric lavage will often terminate otherwise unpalliated vomiting episodes. Distressing diarrhea, likely to be characteristic of enterostomy and enteroenterostomy cases, responds usually to careful dietetic management supplemented by such preparations as kaolin, pectates, magnesium and aluminum hydrogels, and paregoric. Anodyne and antispasmodic suppositories have also their useful indications.

Endocrine derivatives and synthetics as previously mentioned^{20, 26} now loom large in the palliation of various neoplastic diseases. Thus, testosterone and more lately diethylstilbestrol, especially in postmenopausal cases of metastatic breast cancer, appear to bring about temporary improvement in some cases.^{55b} Stilbestrol in the opinion of some workers has supplanted orchietomy as a treatment of choice in cancer of the prostate with osseous dissemination.²⁰ Adrenal medullary cortical extracts and hormone synthetics in con-

junction with the administration of saline solution is indicated⁶³ where a secondary Addison syndrome supervenes.

The local treatment of foul infected ulcerating or fungating lesions, in addition to electrosurgical excision and radiation, has profited by several new techniques. Systemic use and local application of the sulfonamides or penicillin may control infection to a noteworthy extent. Zinc peroxide, azochloramid, and



Fig. 1 (Case 2, M.B.).—Basal-cell carcinoma of nose and lip, recurrent and advanced.



Fig. 2 (Case 3, A.R.).—Squamous-cell carcinoma of forehead, scalp, and eyebrow; osteomyelitis of frontal bone.

eucupine ointment are of adjuvant worth in this respect.^{28, 64} Such old standbys as Dakin's solution, potassium permanganate, and gentian violet may be advantageously employed. Zinc oxide, kaolin, paraffin suspensions, and bronze-aluminum powder may counteract the surface excoriations produced by irritating fistula, colostomy, and ureterostomy discharges. Decubitus ulcers should be prevented by such means as maintaining adequate blood protein levels, and avoidance of pressure by the use of inflated rubber cushions, squares of sheepskin, frequent changes of bedding and position, and skin massage.

Physical Therapy.—Although cryotherapy is no longer considered of much value in the palliative treatment of cancer, amputation using local refrigeration anesthesia is worth while in selected cases. Occasional employment of such modalities as diathermy and moist heat may afford relief, but as a rule physiotherapy has little to offer in this field. Diathermy and fever therapy have been reported as promising sensitizing agents augmenting the effect of irradiation. This work, however, is still at the experimental stage.⁷⁷



Fig. 3 (Case 6, J.D.).—Squamous-cell carcinoma of lip, recurrent, with extension to chin and gingiva.

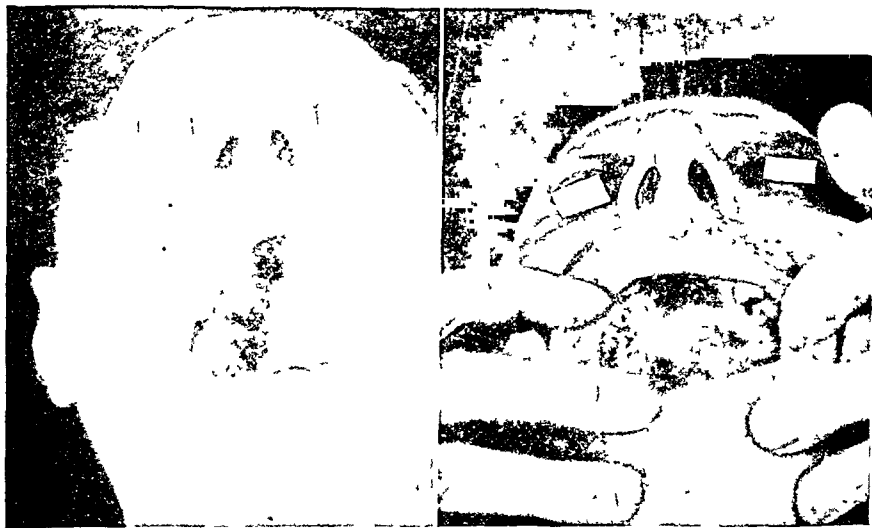


Fig. 4 (Case 8, J.C.).—Mixed tumor of palate, recurrent, with large ulceration and palatal perforation; patient likewise has prostatic carcinoma with pelvic metastases.

Psychotherapy.—Of paramount importance here are the attitude of the physician and provision of thorough and sympathetic efficient nursing care. Hopelessness will handicap the incentive of the doctor, and lead to his regarding the task as a disagreeable chore. Emphasis on what can be offered the patient in the way of the most comfortable prolongation of life must be kept uppermost in mind and impressed upon the family. The morale of the patient can best be maintained by an optimistic and cooperative approach on the part of both inti-

mates and medical attendants. Although no invariable routine can be recommended, the physician generally does best by not committing himself to the patient concerning absolute incurability and life expectancy. Parrying the inevitable questions and countering with psychically helpful suggestions requires tact, understanding, and patience. Keeping the patient as active and as completely engaged as his physical condition warrants is of inestimable worth. Exceptional individuals are capable of maintaining a philosophic poise and ad-



Fig. 5 (Case 9, CS).—Squamous-cell carcinoma of floor of mouth; mandibular involvement, cervical metastases.



Fig. 6 (Case 10, WI).—Squamous-cell carcinoma of tonsil, involving fauces, soft palate, and posterior pharynx.

mirable equanimity given full realization of the gravity of their condition. However, this, too, can be made to endure successfully only when pain and distress are adequately counteracted by judicious therapy.

CLINICAL REPORTS

Comprehensive reports of end results in a large series of patients given palliative treatments for advanced cancer seldom appear in the literature for sites other than the breast or prostate. Published studies generally are concerned with primarily curable cases and scant consideration is given those

dismissed as advanced beyond this degree. Consequently, valid evaluation of the efficacy of palliative treatment demands the future accumulation of considerable further data. The natural yardstick for the accurate estimation of success in such therapy is the longevity of comparable untreated patients. The tendency to allocate patients too desperately ill for even remedial procedures to control groups must be guarded against.^{18, 19, 48}



Fig. 7 (Case 17, K.B.).—Adenocarcinoma of breast; advanced ulcerative lesion invading ribs, with metastases to axilla and spine.

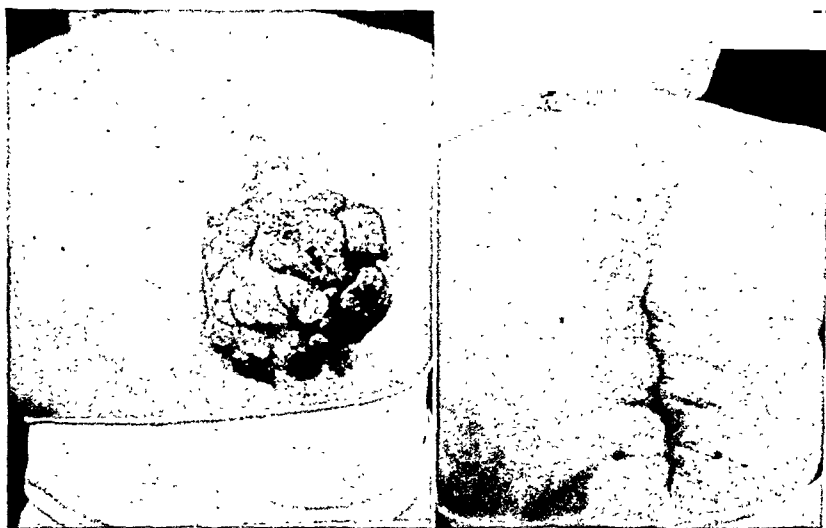


Fig. 8 (Case 25, M.K.).—Neurogenic sarcoma of back; recurrent, ulcerative, and fungating; deeply invasive.

Available clinical experiences do permit one to draw these general conclusions. The duration of life is appreciably longer in treated than untreated groups of patients, and three-year survivals are relatively frequent in the former and rare in the latter. That symptomatic relief can be attained whether or not life is actually prolonged has been amply attested to by many radiologists and surgeons. Moreover, a small unpredictable percentage of cures in apparently irreclaimable malignancies has been reported. Postexploratory withdrawal of supportive therapy from the large group of patients found to be in-

curable is to be condemned. Early postoperative mortalities cannot but discourage other prospective cancer sufferers and in large measure frustrate the public health campaign of education concerning prompt diagnosis and treatment.



Fig. 9 (Case 32, M.S.).—Adenocarcinoma of sigmoid; multiple recurrences, with prolapse of colostomy stoma.



Fig. 10 (Case 41, H.G.).—Squamous-cell carcinoma of leg; recurrent advanced lesion with inguinal ulceration and lymph node involvement.

Selected cases of forty-two patients treated at the Brooklyn Cancer Institute were presented in detail at the 1944 session of the Medical Society of the State of New York as examples of what persistent and intensive therapy might accomplish in lesions of this type. The only cases included were those in which the patients had been initially referred to the institution with advanced and recurrent cancers beyond attempts at cure, who were ambulatory, active, and in relative comfort at the time of presentation. Survival periods range from two and one-half to fourteen years, and average four and one-half years. The cases presented are too small a sample for valid statistical analysis. The patients receiving their initial therapy at Brooklyn Cancer Institute and later requiring secondary treatment are excluded. Similarly, several hundred pa-

TABLE I. DATA ON FORTY-TWO REPRESENTATIVE CASES OF ADVANCED AND RECURRENT

TO B.I

CASE	PATIENT	AGE (YR.)	SEX	B. C. I. ADMIS- SION DATE	SITES	PATHOLOGY	STATUS ON ADMIS- TO B. C. I.
1	F. L.	43	F	1937	Head, face, neck	Basal- and squamous-cell carcinomas	Recurrent and extensive lesions 1-6 cm. in diameter
2	M. B.	64	F	1940	Face, nose, lip	Basal-cell carcinoma	Recurrent extensive ulcerating lesion 7 in largest diameter
3	A. R.	56	M	1939 (N.Y.C.I.) 1942 (B.C.I.)	Scalp, forehead, eyebrows	Squamous-cell carcinoma	Advanced ulcerating recurrence, invasive osteomyelitis of frontal bone
4	H. C.	46	M	1937	Lip, chin	Squamous-cell carcinoma	Large recurrent ulceration, spread to maxillary, salivary and cervical lymph glands
5	H. E.	63	M	1940	Lip, chin, cheek	Basal-cell carcinoma	Recurrent large ulceration
6	J. D.	61	M	1938	Lip, chin, gingiva	Squamous-cell carcinoma	Recurrent large ulcerating lesion
7	H. S.	53	M	1940	Mandible	Adamantinoma	Floor of mouth and cheek
8	J. C.	73	M	1940	(A) Hard palate (B) Prostate	Mixed tumor Adeno- carcinoma	Recurrent with large ulceration Pelvic metastases
9	C. S.	60	M	1938	Floor of mouth	Squamous-cell carcinoma	Recurrence, mass cervical glands to jaw; mandible involved
10	W. I.	51	M	1940	Tonsil, fauces, oral cavity	Squamous-cell carcinoma	Recurrent large ulcerating and fungating lesion
11	W. S.	52	M	1939	Larynx and hypopharynx	Prickle-cell carcinoma	Recurrent advanced intrinsic spread
12	B. F.	58	M	1940	Larynx, epiglottis, base of tongue	Squamous-cell carcinoma	Recurrent advanced ulcerating lesion
13	B. P.	40	F	1940	Thyroid	Adeno- carcinoma	Recurrent neck mass pulmonary metastases
14	F. C.	35	F	1930	Shoulder, arm	Round-cell carcinoma	Advanced recurrence with involvement of shoulder joint and humerus
15	J. B.	32	F	1940	Breast	Medullary carcinoma	Skin recurrences, ulcerated osseous metastases including skull, extremities and pelvis

RESENT AMBULATORY, SURVIVING AN AVERAGE OF FOUR YEARS AFTER INITIAL ADMISSION
TO INSTITUTE

DIAGNOSIS	PRIOR THERAPY	RADIATION AND RADIUM	SURGICAL PROCEDURES	"SALVAGED" YEARS ACTIVE SURVIVAL	STATUS
Excision, infection, no involvement	Radiation	Repeated courses	Repeated electrosurgical excisions	7	Arrested
Forming erosion of nasal cavity, lower orbit	Radiation	Repeated courses	Partial excision and plastic	4	Cure(?)
Ulcer, osteomyelitis, abscess	Radiation	Repeated courses	Repeated electrosurgical excision at N. Y. C. I. of lesion, frontal bone plastic repair	5	Cure(?)
Excision, infection to mandible	Radiation	Repeated courses	V-Resection lip, block dissection neck, resection submaxillary salivary gland	7	Cure(?)
Excision, infection	Radiation	Repeated courses	Dental	4	Cure(?)
Excision, infection	Radiation, caustics	Repeated courses	Dental	6	Cure(?)
Displacement of tongue	Radiation, partial excision	-----	Resection mandible	4	Cure(?)
Partial resection	Radiation	Repeated courses	Palatal resection and plastic repair	4	Improved
-----	-----	Repeated courses	Orchiectomy + (stilbestrol)	4	Improved
Excision, ulcer, abscess of mandible	Radiation	Repeated courses	Carotid ligation, resection of mandible; block dissection of neck	6	Cure(?)
Excision, infection	Radiation	Repeated courses	-----	4	Cure(?)
Trachea, dysphagia	Radiation	Repeated courses	Tracheotomy, laryngectomy	5	Cure(?)
Trachea	Radiation	Repeated courses	Electrosurgery	4	Cure(?)
Excision	Thyroidectomy	Repeated courses	Repeated excision neck tumor	4	Improved
Excision, osteomyelitis, excision	Radiation, 3 resections	Repeated courses	Disarticulation, amputation	14	Cure
Excision, fracture of spine	Radical mastectomy, radiation	Repeated courses	Orthopedic	4	Improved

CASE	PATIENT	AGE (YR.)	SEX	B. C. I. ADMIS- SION DATE	SITES	PATHOLOGY	STATUS ON ADM TO B. C. I.
16	C. K.	71	M	1941	Breast	Adeno- carcinoma	Recurrent, large ing lesion
17	K. B.	46	F	1939	Breast	Medullary carcinoma	Advanced ulcerat lesion, metastas spine, rib
18	M. L.	65	F	1937	Breast	Adeno- carcinoma	Advanced bulky t with axillary m tases
19	W. W.	63	M	1939	Breast	Adeno- carcinoma	Advanced, large f ing tumor invol axillary glands ribs
20	M. B.	42	F	1940	Breast	Medullary carcinoma	Multiple skin nodu metastases to sk pelvis, long bones
21	E. S.	34	F	1941	Breast	Adeno- carcinoma	Pelvic metastases; clavicular glands
22	E. R.	23	F	1935	Axilla and chest wall	Neurogenic sarcoma	Extensive ulcerativ fungating recurr
23	M. H.	37	F	1940	Neck	Malignant lymphoma	Involving skull, rit cervicothoracic s hips, long bones,
24	L. M.	50	F	1940	Chest wall and ribs	Osteochondro- sarcoma	Large recurrent ma chest wall involvi 5th, 6th, 7th ribs
25	M. K.	52	F	1940	Back	Neurogenic sarcoma	Recurrent extensive gating lesion fron to 8th rib
26	J. A.	4 mo	F	1941	Retro- perito- neal	Neurocytoma	Advanced, large abd nal tumor
27	M. S.	11	F	1940	Kidney	Hyper- nephroma	Recurrent large abd nal mass
28	S. N.	58	F	1938	Stomach	Adeno- carcinoma	Advanced gastric car palpable mass
29	M. K.	58	M	1941	Stomach	Adeno- carcinoma	Postlaparotomy, inop able lesion
30	J. D.	40	M	1942	Jejunum	Adeno- carcinoma	Large papillary lesion
31	E. G.	64	F	1941	Cecum	Adeno- carcinoma	Large peristomal recn rent mass
32	M. S.	65	M	1938	Sigmoid	Adeno- carcinoma	Extensive multiple per colostomy and abdom nal wall recurrences

NT'D

PLICATIONS	PRIOR THERAPY	RADIATION AND RADIUM	SURGICAL PROCEDURES	"SAV- VAGED" YEARS ACTIVE SURVIVAL	STATUS
ration, ection	Partial excision	Repeated courses	-----	3	Cure(?)
ration, ection	-----	Repeated courses	-----	5	Improved
ration chest l axilla	-----	Repeated courses	-----	7	Arrest
ration, ection	Radiation	Repeated courses	Radical mastectomy	5	Cure(?)
iple skin ons	Radical mastectomy, radiation	Repeated courses	Local recurrence, ex- cisions	4	Improved
phedema of	Radical mastectomy	Repeated courses	Paravertebral injection	3	Improved
invasion	Partial excision	Repeated courses	Secondary radical re- section	9	Cure
ologic cture hip	Laminectomy, cord decom- pression	Repeated courses	Orthopedic	4	Improved
ration, ection	Partial excision, radiation	Repeated courses	Secondary radical re- section	4	Cure
ration; ection	Excision, radiation	Repeated courses	Secondary radical re- section, skin grafts	4	Cure
veral and ial displace- nt	Radiation	Repeated courses	Radical resection	3	Cure(?)
ensive retro- itoneal owth, renal mpression	Partial excision, radiation	Repeated courses	Secondary radical re- section	4	Cure(?)
ensive tumor nsidered perable 1 r before	Radiation	-----	Subtotal gastrectomy	6	Cure
ensive re- nal spread	Laparotomy	Repeated courses	-----	3	Improved
h intestinal truction	Gastro- enterostomy, radiation	-----	Radical enterectomy	2½	Cure(?)
ration, urrence, ostomy struction	Mikulicz type resection	Repeated courses	Secondary radical re- section	3	Cure(?)
ration, ection, stomy struction	Obstructive resection	-----	Repeated electrosurgical excisions and colos- tomy revision	6	Arrested

Case	PA- TIENT	AGE (YR.)	SEX	B. C. I. ADMIS- SION DATE	SITES	PATHOLOGY	STATUS ON ADMIS- SION TO B. C. I.
33	O. L.	50	M	1940	Colon, splenic flexure	Gelatinous adeno- carcinoma	Post laparotomy, sive perforating
34	A. G.	55	F	1942	Sigmoid	Adeno- carcinoma	Large peristomal recurrence with involv- ment of inferior mesen- teric glands
35	C. N.	29	F	1936	Rectum	Adeno- carcinoma	Large postoperative recurrence
36	H. K.	38	F	1939	Ovary	Papillary cystadeno- carcinoma	Postlaparotomy for large extensive dominal mass
37	R. C.	55	F	1938	Cervix	Squamous-cell carcinoma	Recurrent extensive lesion, Schmitz I
38	M. F.	61	F	1938	Cervix	Squamous-cell carcinoma	Extensive lesion, Sel- IV; metastases to pelvis and spine
39	K. E.	59	F	1937	Vulva	Squamous-cell carcinoma	Recurrent extensive ulcerative lesion, labia and perineum
40	M. S.	64	M	1942	Prostate	Adeno- carcinoma	Generalized rarefied skeletal metastases especially pelvis, spine, long bones
41	H. G.	31	F	1941	Leg	Squamous-cell carcinoma	Large recurrent fun- gus lesion, massive involvement of groin and inguinal node
42	J. S.	44	M	1940	Foot	Malignant melanoma	Large local recurrence with massive involv- ment popliteal, ingu- inal, and pelvic para-aortic glands

patients in whom satisfactory palliation of several years' duration had been achieved, but who had died or were incapacitated by malignant disease at the time of the study, were not utilized. What fraction this group comprises of the entire body of patients referred to the Cancer Institute for purely palliative or custodial care cannot, unfortunately, be determined. However, in our overall estimation, 70 per cent of the patients admitted are definitely benefited by palliative methods of treatment and some 5 per cent of advanced cancer patients may be considered as salvaged. This compares not unfavorably with an approximate five-year cure rate of 18 per cent generally reported for all cancers.

With only three exceptions all patients received secondary radiation, radium, or radon therapy, usually in several cycles. The techniques used varied considerably, in view of the variety of neoplasms treated, and are therefore not detailed, but total amounts comprised adequate accepted tumor lethal doses in all instances. The series is constituted as follows: nine advanced re-

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most of the remainder, radical secondary resection with hope of tumor extirpation was carried out. In several instances radiation alone sufficed. The operative procedures included carotid ligation, block dissection of neck, mandibular resection, laryngectomy, disarticulative amputation, radical inguinal and retroperitoneal dissection, gastrectomy, secondary enterectomy, abdominoperitoneal resection, panhysterectomy, and orchiectomy. There were six successfully treated pathologic fractures in the series, three of the spine and three of the hip, receiving a combination of orthopedic and radiologic treatment.

The average survival of four and one-half years is in each patient attributable to intensive and repeated roentgen therapy and surgical treatment, most often in combination. This assumption is borne out by the fact that such grave complications as intractable dysphagia, dyspnea, vomiting, pathologic hip or spine fracture, intestinal obstruction, hemorrhage, obstructive hydro-nephrosis and pyelonephritis, infection or toxemia had already supervened in most cases. In twenty-four patients presumptive cures and in nine instances definite arrest have been attained; the remainder are notably improved. The major features of each case are presented in some detail in Table I.

CONCLUSION

Both the variable neoplastic growth rates encountered and the incidence of prolonged periods of latency in cancer warrant considerable promise of prolonging life expectancy in many incurable patients with malignant disease. Significant arrest of the tumor process and appreciable augmentation of the comfortable longevity of the patient may in many instances be induced by the judicious administration of surgery, radiation therapy, and medication. On occasion a five-year survival with apparent cure may be achieved. The all too prevalent attitude that nothing can be done overlooks the remarkable progress in remedial therapy that has been accomplished. Proper management in the majority of primarily inoperable malignancies may accomplish at least as much as in the present-day care of such similarly incurable illnesses as arteriosclerotic and rheumatic heart disease or hypertension and nephritis. Abandonment of the large group of patients with incurable cancer to uncontested early mortality after exploratory operation can only frustrate in large measure the campaign of public health education concerning prompt cooperation in cancer diagnosis and treatment. Forty-two patients with palliatively treated advanced cancer now surviving an average of four and one-half years are presented.

The fact that at present some four-fifths of all cancer patients are ultimately candidates for palliative treatment makes the exaction of the total potential life and comfort salvage in this group a public health problem of tremendous significance. The relief of pain and discomfort, the eradication of distressing primary and secondary lesions, the control of hemorrhage and infection, the recession of osseous metastases and healing of pathologic fractures, the successful management of dyspnea, dysphagia, and cough, and the postponement of regional and systemic spread of the primary neoplasm are among the desirable results achieved by the great armamentarium of modern palliative methods. In the province of advanced cancer this paraphrased dictum is truly applicable, "the physician can cure on occasion, help often, but provide comfort always."

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A REVIEW OF 101 SUBTOTAL GASTRECTOMIES FOR BENIGN ULCER

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THE 101 subtotal resections upon which this study is based have been performed during the past eleven years. It has been our policy to be neither the first nor the last in the adoption of an operation, and neither too conservative nor too radical in its practice. With added experience, however, it is but natural that our viewpoint has broadened and, in common with other surgeons, we have increased the scope of the procedure. We therefore feel that the findings, treatment, and results in these 101 cases are probably representative and may be of some value in an estimation of the indications, extent, and efficacy of resection of the stomach for benign gastric ulcer and for duodenal ulcer and its complications, according to modern conception.

GASTRIC ULCER

In selecting our patients with gastric ulcer for resection, we have always regarded chronic perforation, hemorrhage, obstruction, and associated extensive gastritis as definite criteria. Operation in such cases should be delayed only while the patient is being prepared, as these lesions are recalcitrant to medical treatment and continued conservative management is both useless and dangerous. In that more indefinite group, the uncomplicated ulcers, we have occasionally been somewhat less certain as to the proper course to pursue. Formerly, we were inclined to temporize with medical management unless malignancy seemed probable. Within recent years, we have taken a more aggressive course. We have appreciated more and more the fact that evidence of healing of a gastric ulcer after a period of medical treatment by no means signifies that the lesion is benign. By far the majority of carcinomas will also respond temporarily to medical measures. Not only this, but ulcer may be indistinguishable clinically from carcinoma. The usual ulcer symptoms in a comparatively young individual, associated with high stomach acids and a roentgenographic picture of a small lesion may also apply to carcinoma. In a study of our own cases of gastric cancer, we found that a preoperative diagnosis of ulcer was made in 22 per cent, and in a few others a distinction could not be made between ulcer and carcinoma prior to operation. Walters⁷ reported that in 33 per cent of the cases of carcinoma of the stomach in which operation was performed at the Mayo Clinic over a period of thirty-two years, the characteristic symptoms of ulcer were described in the history. Further, Judd and Priestley⁵ found that approximately 7 per cent of patients who have a resection for malignancies of the stomach are less than 40 years of age; approximately 9 of 10 carcinomas are 4 cm. or less in diameter; and a roentgenographic diagnosis of ulcer is made in approximately 10 per cent of carcinomas proved at operation. Again, the possibility of diagnostic error is forcefully demonstrated by Allen and Welch.¹ They report that of 69 patients subjected to gastric resection with a preoperative diagnosis of ulcer, 30, or 43 per cent, had a final diagnosis of cancer by the pathologist. Further, of 175 patients treated medically for ulcer, 13 were

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eventually found to have cancer. They regard this as an illustration of the difficulty of making a true diagnosis even while the lesion is under observation.

Nor is the *location* of the ulcer a definite indication of its benign or malignant nature. As a rule, lesions situated at the pylorus or in the antrum and on the greater curvature are malignant, whereas those in the mid-portion or proximal half and on the lesser curvature of the stomach are more often benign. Even in the latter areas, however, the potentiality of cancer is by no means negligible; at least one-third of the lesions so situated are malignant.

In so far as symptomatic relief is concerned, statistics indicate that medical treatment is curative in less than one-half the cases of gastric ulcer. Many patients must follow a medical regimen continuously for an indefinite period, and every one should have frequently repeated roentgenographic studies until cure is fairly certain. On the other hand, gastrectomy may be relied upon to relieve the symptoms completely or at least materially in almost 100 per cent of cases. Added to this, resection eliminates the danger of malignancy and practically eliminates the danger of a recurrent ulcer. In our experience, patients have obtained uniformly good stomach function, and thus far none has exhibited signs of a recurrent lesion.

The mortality of gastric resection in properly selected cases cannot well be held as an argument against its use. In the presence of an ulcer situated high on the lesser curvature, one must often compromise upon gastroenterostomy. The general condition of the patient may also prohibit resection. When the location of the ulcer permits and the patient is a suitable risk, the operation should be performed with a mortality of not over 5 per cent, which is only one-half the percentage of malignant degeneration.

Considering this fact and the fact that medical measures are curative in not more than 50 per cent of cases, whereas the prospect of permanent relief by resection is excellent, both medical and surgical opinion are tending more and more toward the latter procedure as the treatment of choice for uncomplicated gastric ulcer. Conservative management is reserved for those in an obviously early stage of development, preferably in the proximal portion of the stomach. If the symptomatic and roentgenographic signs disappear within three or four weeks, one may then feel that operation may be safely withheld so long as frequent checkup roentgenograms remain negative. Persistent or recurrent symptoms and signs after this brief period of medical treatment are regarded as definitely indicating surgery.

DUODENAL ULCER

The observer of trends in the treatment of duodenal ulcer cannot but be impressed with two facts: first, that although this lesion is now recognized as being an essentially medical disease, the number of patients who require surgery has not decreased. A review of our own cases over the past eleven years reveals that now approximately 33 per cent of patients with duodenal ulcer come to operation, whereas prior to this period approximately 30 per cent required surgery. Our criteria for operation having remained unchanged, we have no explanation for this other than that we are seeing more patients with surgical ulcers. Second, our conception of the choice of operation has been considerably altered. Acute perforations, constituting approximately 16 per cent of the duodenal ulcers we have seen which demand surgery, are usually treated by simple closure. Parenthetically, it is worthy of note that even in certain of these cases a few surgeons are now employing resection. Aside from this group, however, palliative surgery has to a large extent been replaced by

resection. Pyloroplasty has been abandoned almost entirely, and gastroenterostomy is employed by most surgeons only when the condition of the patient precludes the more radical operation, or when the lesion is situated so far distally on the duodenum as to encroach upon the common duct. We have not performed a pyloroplasty in our clinic since 1939, and in that year performed only one. In 1940, resection was done in one-half of our patients with primary duodenal ulcer, and gastroenterostomy in the other half; today three-fourths are treated by resection. Other clinics report a similar experience. Walters and his associates⁵ reported that in 1940 gastroenterostomy constituted 55 per cent of operations for duodenal ulcer at the Mayo Clinic, and gastrectomy a little over 40 per cent. In 1942, this was reversed; gastrectomy was performed in over 57 per cent, while gastroenterostomies fell to approximately 41 per cent. Marshall⁶ reported that at the Lahey Clinic during the past seven years, 395 patients were operated upon for peptic ulcer, aside from those with acute perforation. Of this 395, subtotal resection was performed in 318 and gastroenterostomy in 75 cases. Hinton⁴ stated that he has performed subtotal gastric resection exclusively in his cases of chronic gastric and duodenal ulcer since 1932. All this means that surgeons have become convinced of the superiority of resection over gastroenterostomy when such a course is feasible. Further, one cannot overlook the fact that improved methods of preoperative treatment have made the procedure feasible in an increasing number of cases.

It has been our custom to advise resection in the presence of one or more of the following complications: (1) recurrent hemorrhage, (2) obstruction, (3) intractable pain, and (4) recurrent or reactivated ulcer.

Hemorrhage.—Primary resection has been performed for repeated episodes of bleeding in one-third of our surgical cases. Operation has been limited to those patients in whom the hemorrhage recurs often and is associated with long-standing symptoms of ulcer, particularly *pain*. On exploration, an ulcer is usually found on the posterior duodenal wall, its base extending deep into the pancreas. As a rule, the bleeding is produced by erosion of one of the larger pyloric group of vessels. The pain is generally due to edema and obstruction incident to a more or less severe inflammatory reaction of the pancreas, as well as to acid corrosion of the ulcer and pylorospasm. Not infrequently, an anterior ulcer is likewise present, and occasionally one encounters an anterior ulcer which itself is hemorrhagic.

If the hemorrhage is of massive proportions, there may be some question as to the advisability of operating immediately or delaying the procedure. In young individuals, that is, under 45 years of age, we feel that operation is indicated only if transfusions and other supportive treatment fail to control the bleeding and raise the blood pressure to a satisfactory level within thirty-six to forty-eight hours. With few exceptions, a clot will form and close the opening of the bleeding vessel in this group of patients. Not infrequently, the hemorrhage is the first evidence of ulcer and the patient has had no opportunity to try medical treatment. If the ulcer is of long standing, however, and medical treatment has been given an adequate trial, we believe resection is advisable as soon as the patient sufficiently recovers. In any event, a second massive hemorrhage is a definite indication for operation. A single massive hemorrhage in patients beyond the age of 45 is more serious. The arterial walls are less elastic and the formation of a clot is less likely. In this group it is best to operate within twelve to twenty-four hours unless continuous or repeated transfusion brings about a definite improvement; even so, operation should be per-

formed as soon as feasible following cessation of the hemorrhage. We have had only a few patients whose hemorrhage could be classified as massive, all of whom have recovered. Reports of large series, however, have shown that operation for massive hemorrhage in individuals over 45 years of age carries a high mortality, especially if the procedure is delayed beyond the first twenty-four hours after onset.

Obstruction arising from inflammatory edema of an otherwise uncomplicated ulcer may generally be overcome by medical treatment. On the other hand, in the presence of edema associated with a penetrating posterior lesion combined with a cicatrizing anterior ulcer, resection becomes necessary; medical treatment is advisable only as a preoperative measure, or the obstruction may be of such long standing as to have produced an enormous dilatation of the stomach and to be entirely unresponsive to conservative management. In these cases, we believe resection affords the only promise of relief. We have recently encountered a lesion of the latter type in a woman, aged 36 years. She had had attacks of abdominal pain for as long as she could remember, and definite ulcer symptoms for fifteen years. During recent years she had vomited daily. Having undergone many examinations and much treatment, with no relief, she was referred to us for surgery. Our examination revealed, in addition to the obstructing duodenal lesion, an enormous stomach, the greater curvature lying on the pelvic floor when the patient was in the standing position. These findings were confirmed at operation. An anterior ulcer, which had slowly perforated and was being protected, was producing an almost complete obstruction. The stomach was twenty inches or more in length and of commensurate depth, its walls exceedingly edematous. A subtotal resection was followed by prompt relief of symptoms.

In this connection, the presence of an anterior ulcer should always lead one to suspect a posterior lesion as well, whether indicated by the symptoms or not. It is now well known that the majority of ulcers are multiple, and unless a careful search is made a posterior lesion may go undetected. Frequently, it is necessary to open the stomach to bring the latter into view. We have encountered multiple lesions in 62.5 per cent of the primary resections we have done for ulcer.

A small number of patients with ulcer, usually those past middle age with a history of constant or recurrent symptoms covering many years, require operation because of mechanical obstruction at the pylorus incident to the long-standing inflammation and consequent cicatrization. Formerly, this was the one complication for which gastroenterostomy was considered ideal. Experience has shown that it is the one most amenable to cure by gastroenterostomy; the stomach acids are practically always low and the result generally excellent. Nevertheless, within the past two years we have been performing resection in this group of patients, also, as the procedure of choice. There are several reasons for this change of attitude. In the first place, the stomach is considerably enlarged and the small gastroenterostomy opening does not permit the contents to empty quickly enough. Second, the patient has a much quieter and more rapid convalescence. Third, the technical procedure is more easily executed, there being no firm adhesions between the duodenum and pancreas. Fourth, by removal of the ulcer-bearing portion of the stomach we have every assurance that we have permanently rid the patient of his disease. Although the likelihood of recurrence following gastroenterostomy in these cases is remote, it is certainly worth considering.

Intractable pain, which is practically always accompanied by high acid values and the digestive symptoms of ulcer, is our major reason for resection in a large proportion of cases. Realizing the difficulty of relieving these patients by any type of treatment, we have attempted to select them with care. Operation has been advised only after prolonged medical treatment has proved ineffectual or if the patient has shown himself incapable of following a medical regimen for occupational or other reasons. On exploration, one usually finds both an anterior and a posterior ulcer, the latter penetrating into the pancreas and being chiefly responsible for the persistent symptoms. After operation, it is often necessary to observe the patient at brief intervals for an indefinite time. This is especially true of those of unstable temperament, since such individuals will frequently continue to complain, despite every physical and roentgenographic appearance of an excellent result.

Gastrojejunal ulcers are observed most often in young or middle-aged individuals with high acid values who have had a gastroenterostomy. Many of them appear within a few days or a few weeks following operation, and the majority manifest themselves within eighteen months. Although years may elapse before the patient comes to surgery, the history will usually reveal that the symptoms recurred within a short while after operation. The symptoms, however, are not quite typical: the pain is slightly lower and more to the left, is more constant and severe, and is seldom completely controlled by food or alkali. Bleeding, often serious, has been associated in one-third of our cases.

According to our observation, medical treatment for these ulcers gives only temporary relief. For this reason, we regard operation as imperative as soon as the patient can be prepared. Perforation into the peritoneal cavity, and especially into the transverse colon, is always a possibility. Frequently, also, the necessity for operation is increased by the presence of an active duodenal ulcer. During the past eleven years we have operated upon eight patients for gastrojejunal ulcer, all except one of whom had an associated duodenal ulcer. One patient had not only a duodenal ulcer, but two gastrojejunal ulcers, one penetrating into the pancreas and one into the colon. In 3 of the 8 cases the gastrojejunal ulcer had penetrated onto the transverse colon, and in an additional 2, or 25 per cent, a gastrojejunocolic fistula was present.

Extent of Operation.—Experience has shown that the ultimate success of gastric resection depends chiefly upon its extent. The object of the operation is the control of hypermotility and hypersecretion and, by this means, relief of the patient's symptoms. It is now well known that the major factor in recurrent ulcer following resection is failure to remove the pylorus and antrum, this being the portion which is largely responsible for activity of the acid-bearing cells. Thus, the operation should invariably be one which completely extirpates the antrum, pylorus, and ulcer. If such a procedure is not technically feasible because of extensive ulceration or inflammatory reaction, it is better to be content with a gastroenterostomy; if necessary, an adequate resection may be performed after a period of physiologic rest.

Follow-up studies have proved that, with few exceptions, 55 to 65 per cent of the distal portion of the stomach, together with the ulcer, is ample to fulfill all the requirements of resection for primary duodenal ulcer. Some surgeons, however, consider it advisable to resect three-fourths or more, contending that absolute achlorhydria is essential to prevent recurrence. With this we cannot agree. The disturbance of gastric function and the total anacidity incident to such wide resections may lead to serious nutritional deficiencies. Friedell,

Sharr, and Walters³ found that when one-half or more of the stomach, including the pylorus and antrum, is removed, a permanent reduction of the free hydrochloric acid in the fasting contents follows, and this reduction is to 0 in 75 per cent of cases. If more than this amount is removed, there is only a slight increase of the incidence of the reduction to 0. The remaining 25 per cent does not obtain relative achlorhydria, even though the entire pylorus is resected. It seems quite likely, as they suggest, that marginal ulcers following resection develop in the 25 per cent; unquestionably, those who are not completely relieved are in this group. Church and Hinton² reported that 46 per cent of their patients had no free hydrochloric acid postoperatively, including not only those who were regarded as cured, but also a number who were merely benefited and even unimproved. We have found that a relative achlorhydria gives excellent results and see no point in depriving the patient of any more of the stomach than is necessary. In fact, it is our conviction that removal of 50 per cent for primary duodenal ulcer in a patient with low acids is just as effective as the more massive resection, and that excision of more than two-thirds is unwarranted unless the acids are excessive or an extensive gastritis is present. A recurrent or marginal ulcer, of course, demands a higher resection. These patients are unlikely to be relieved entirely by any method of treatment, though we may reasonably promise them a comparatively comfortable existence by removal of 75 to 80 per cent of the stomach. Even so, medical treatment for an indefinite period after operation is often advisable.

The Polya type of anastomosis is employed routinely in all our gastrectomies. Formerly, an effort was made to reconstruct the continuity of the intestinal tract posterior to the colon in every case. More recently, however, we have been using the antecolic anastomosis, as suggested by Balfour, in an increasing number. With these techniques, we believe the acid factor is better controlled by reason of the rapid emptying, which limits the admixture of acid with the stomach contents, and by reason of the fact that the maximum amount of bile is admitted into the stomach through the larger opening. During the early postoperative period, too rapid emptying is prevented by spastic contraction of the jejunum, and after healing is complete the jejunum acquires a certain immunity to the stomach acids and itself assumes some degree of digestive function. In addition to these features, obstruction incident to adhesions or to contracture of the stoma from scar tissue is less likely following the Polya anastomosis.

We have never performed an additional enteroenterostomy, even in our highest resections for ulcer. This procedure is not only unnecessary, but tends to prevent a material reduction in gastric acidity and thus increases the danger of recurrence.

ANALYSIS OF CASES

In making this study, we have reviewed all our cases of gastric, duodenal, and gastrojejunal ulcer over the past twenty-six years, comprising a total of 1,218. Of this number, 1,147 (94.2 per cent) were duodenal, 45 (3.7 per cent) were gastric, including 8 in which both a gastric and duodenal ulcer were present, and 26 (2.1 per cent) were gastrojejunal. These figures, together with the number of each type in which operation was performed, are shown in Table I.

As may be seen, in our experience the incidence of gastric ulcer has been quite low in proportion to the incidence reported by others, being 3.7 per cent

TABLE I. PATIENTS WITH ULCER, JANUARY, 1918 TO JANUARY, 1944 (1,218)

	PATIENTS	OPERATIONS	PER CENT
Duodenal ulcer	1,147	350	30
Gastric ulcer (8 duodenal ulcer)	45	27	60
Gastrojejunal ulcer	26	16	60
Totals	1,218	393	32.4

of the entire 1,218, or 1 in every 27. Further, the gastric ulcers for which operation was done were only 7 per cent of the total of 393 surgical ulcers. We have no explanation for this, as we have been most careful to locate every ulcer definitely and to record its location.

For purposes of comparison, the series of 1,218 ulcers has been divided into two groups: those observed prior to January, 1933, when we first began the use of gastrectomy for duodenal ulcer, and those from 1933 to 1944. The distribution of the ulcers and the operations performed are shown in Tables II and III.

TABLE II. PATIENTS WITH ULCER, 1918 TO 1932, INCLUSIVE (600)

	PATIENTS	OPERATIONS	PER CENT
Duodenal ulcer	564	167	30
Gastric ulcer (2 duodenal ulcer)	24	12	50
Gastrojejunal ulcer	12	8	66
Totals	600	187	30.1

TABLE III. PATIENTS WITH ULCER, JANUARY, 1933 TO JANUARY, 1944, INCLUSIVE (618)

	PATIENTS	OPERATIONS	PER CENT
Duodenal ulcer	583	183	31
Gastric ulcer (6 duodenal ulcer)	21	15	71
Gastrojejunal ulcer	14	8	57
Totals	618	206	33.4

The cases in these two series are similar in type and number, though the percentage of total operations is slightly higher in the latter group. This holds true even when one omits the operations for acute perforating ulcer, which in the first group is 27 per cent and in the second group, 28 per cent. The types of operations employed in the two groups of cases are shown in Table IV.

TABLE IV. TOTAL OPERATIONS IN 1,218 PATIENTS WITH ULCER, 1918 TO 1944

	CLOSURE PER- FORATION	PYLORO- PLASTY	GASTRO- ENTEROS- TOMY	RESECTION	TOTAL
Group I 600 cases 1918-1932	24	35	125	3	187
Group II 618 cases 1933-1944	33	14	58	101	206
Totals	57	49	183	104	393

These figures clearly show our trend toward resection as the procedure of choice for ulcer during recent years. Of the 3 cases for which resection was done in the earlier group, 2 were for gastrojejunal ulcer and 1 for gastric and duodenal ulcer combined. The lesions for which resection was done in the second group are shown in Table V, together with the mortality.

In 2 cases of gastric ulcer the lesion was so high as to preclude resection and a gastroenterostomy was necessary.

In the 61 operations for primary duodenal ulcer and the 6 for duodenal and gastric ulcer combined, a total of 67, there were 42, or 62.5 per cent, multiple ulcers.

TABLE V. FINDINGS AND MORTALITY IN 101 RESECTIONS FOR ULCER, JANUARY, 1933 TO JANUARY, 1944

	NUMBER	MORTALITY	PER CENT
<i>Primary Operations</i>			
Duodenal ulcer	61	1	1.7
Duodenal and gastric ulcer	5	0	0
Gastric ulcer	7	1	14.3
Totals	73	2	2.7
<i>Secondary Operations</i>			
Duodenal ulcer	19	0	0
Duodenal and gastric ulcer	1	0	0
Gastrojejunal ulcer	6	0	0
Gastrojejunal ulcer with colon fistula	2	1	50
Totals	28	1	3.6
	101	3	3.0

On studying these 101 patients with regard to the *results* of resection, we find that of the 13 patients with gastric ulcer, including those with duodenal ulcer as well, 11 were operated upon from nine months to nine years ago. Of these 11 patients, 10, or 90 per cent, obtained a good functional result and were free of their former ulcer symptoms. The eleventh patient died of a pulmonary embolism on the third postoperative day.

Of the 61 patients with primary duodenal ulcer, 1, or 1.7 per cent, succumbed to pneumonia postoperatively. This, incidentally, was the first patient of the series, operated upon in 1933. Of the remaining 60, 50 were operated upon more than one year ago. Two of these 50 have not been heard from since leaving the hospital. Of the other 48, 33 report an excellent result, with good stomach function and complete relief of their distress. An additional 10 have been materially relieved, though they still have some minor disturbance, such as mild nausea and vomiting after breakfast, or some weakness or stubborn weight loss. These 43 patients represent 90 per cent of results which may be classified as excellent or good. Four patients, or approximately 8 per cent, have clinical and roentgenographic evidence of a recurrent ulcer at the stoma.

The total operative mortality of the 73 patients operated upon primarily was 2, or 2.7 per cent. Of the 28 for whom resection was performed as a secondary procedure, 1 died, this being a mortality of 3.6 per cent. The latter patient was one of the two who had a gastrojejunoecolic fistula. The fistula had been present for six months. Death was due to pneumonia.

It is of interest to study these results of resection for primary duodenal ulcer from the standpoint of the pathologic condition found at operation, as shown in Table VI.

TABLE VI. RESULTS OF GASTRIC RESECTION IN FORTY-NINE CASES OF PRIMARY DUODENAL ULCER

	COMPLETE RELIEF	PARTIAL RELIEF	NO RELIEF	DIED	TOTAL	PER CENT
Bleeding ulcer (7 multiple)	13	4	0	0	17	34.7
Obstructive ulcer (2 multiple)	5	1	0	0	6	12.2
Intractable ulcer (16 multiple)	15	5	5	1	26	53
Totals	33	10	5	1	49	100

It will be seen that 17, or 34.7 per cent, of the patients who were operated upon more than one year ago had a bleeding posterior ulcer, 7 of them with an associated anterior ulcer. Thirteen of the 17 were completely relieved and 4 partially relieved. Thus, the entire 17, or 100 per cent, were benefited by the operation. There were no deaths in this group.

Five of the 6 patients with obstructive ulcers have remained entirely free of symptoms, and 1 still has some nausea with vomiting of bile at times. Two of the 6 had both an anterior and a posterior lesion.

Of the 26 for whom resection was performed for intractable pain, 15 were completely relieved, 5 partially relieved, 4 continued to have considerable discomfort, 1 developed clinical evidence of a gastrojejunal ulcer, and 1 died. Sixteen of the 26 had multiple ulcers.

Although this series is small, it shows that our experience is similar to that of other surgeons, in that obstructive ulcers of the duodenum have been found most amenable to cure, that resection for bleeding ulcer may be expected to give the next best results, and that for intractable ulcers the prospect of complete relief is somewhat less certain.

Of the total of 8 patients for whom resection was performed for gastrojejunal ulcer, all were operated upon more than one year ago. Six have obtained an excellent result, having no symptoms whatever, and 1 has only occasional nausea. These 7 constitute 87.5 per cent of good results. The remaining patient, who had a gastrojejuno-colic fistula as mentioned previously, died, constituting a mortality of 12.5 per cent in the group of 8.

Of the other 19 patients who had resection following a previous operation, 16 came to surgery more than one year ago. Three of these have some slight nausea, and the others report complete relief with a good functional result.

TABLE VII. MORTALITY OF 101 PATIENTS WITH RESECTIONS OF THE STOMACH FOR BENIGN ULCER

	NUMBER CASES	NUMBER DEATHS
Primary duodenal ulcer	61	1
Gastric ulcer (6 with duodenal ulcer)	13	1
Gastrojejunal ulcer	8	1
Reactivated duodenal ulcer	19	0
Totals	101	3 (3%)

In Table VII is presented a composite picture of our mortality of resection for all types of benign ulcer of the stomach and duodenum. In a total of 101 resections, we have had 3 deaths, a mortality of approximately 3 per cent. Considering the nature of the operation and the fact that many patients with these lesions have associated disease which materially increases the risk, we feel that a mortality of 5 per cent or less is certainly commensurate with that of other abdominal procedures of similar magnitude. We have had no deaths from resection in these cases for the past eight and one-half years.

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DICUMAROL IN THE PREVENTION OF POSTOPERATIVE THROMBOSIS AND PULMONARY EMBOLISM

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AT THE time of John Hunter and Cruvelhier, pathologists were of the opinion that thrombosis occurred as a sequel to phlebitis. In 1846, Virchow^{1, 2} began his experimental work on thrombosis and during the next ten years completely revolutionized all existing knowledge on this subject. He demonstrated conclusively that a thrombus is the primary essential condition in phlebitis. He was also the first to recognize pulmonary embolism. This work was his single greatest achievement in pathology and is in every sense his very own.

Postoperative thrombosis and pulmonary embolism have always been a source of great concern to the surgeon. A successful operation coupled with an uneventful subsequent convalescence does in no way guard the patient against a possible fatal embolism.

In a review of the literature³⁻⁵ we find that the incidence of venous thrombosis and pulmonary embolism is 1 per cent of all surgical procedures, 2 per cent of all laparotomies, and 3 per cent of laparotomies performed on women. The occurrence after splenectomy is as high as 5 per cent. Since the platelets are very much increased after the operation this is undoubtedly a contributing factor.

Infection and extensive resection of tissue increase the occurrence of thrombosis and embolism. Other predisposing factors according to Barker and his co-workers are obesity, blood diseases, heart disease, peripheral vascular disease, and malignancy.

Many factors are involved in the production of postoperative venous thrombosis, the most important of which are local changes in the wall of the veins, the rate of venous flow, and disturbances in the coagulation of the blood. According to Neumann⁶ and Voegt,⁷ thrombophlebitis begins in the pelvic venous plexuses where complete stasis is possible or in the venules of the subcutis and muscles of the calves and thighs where prolonged pressure and ischemia cause tissue damage. Complete postoperative bed rest predisposes to lesions in the legs.

Thrombophlebitis rarely occurs in the first four days after operation. It makes its appearance between the fourth and the fourteenth day. Pulmonary embolism, on the other hand, is more often seen between the seventh and the fourteenth postoperative day. When thrombophlebitis does occur, postoperatively, it generally involves the veins of the lower extremities or, if intra-abdominal, the veins of the pelvis. The veins of the left leg are involved twice as frequently as those of the right, the short saphenous being the most commonly affected. Nevertheless, this condition can occur in any of the veins. The

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thrombus may either adhere to the wall of the vein and become organized, or it may detach itself to form an embolus. The degree of pulmonary involvement depends upon the size of the embolus. An embolus arising from the saphenous vein would be relatively harmless, while one from the iliofemoral would be of sufficient size to cause death. After a thrombophlebitis has existed a few days it is less likely to be a source of embolism, for the thrombus has become adherent to the wall of the vein. Most of the cases of pulmonary embolism arise from so-called silent thrombophlebitis which cannot be diagnosed. Even at autopsy in cases of fatal pulmonary embolus it is often impossible to find the etiologic thrombophlebitis.

Post-mortem studies have shown that many patients suffered from repeated small pulmonary emboli until one was of sufficient size to be fatal. This emphasizes the importance of prompt treatment in cases of small multiple emboli.

Until recently there was no effective treatment for postoperative thrombosis and pulmonary embolism. Some surgeons^{8, 9} hoped to prevent this condition by having the patient get out of bed a day or two after the operation. The purpose of this was to improve the circulation in the lower extremities. Other less drastic physical measures recommended were turning the patient frequently to elevate the lower extremities and to exercise them. It was also advised to have patients breathe deeply and cough in order to keep the lungs clear and well aerated. Newer methods include paravertebral procaine sympathetic block¹⁰ and venous section and ligation.¹¹

In 1924, Mason¹² reported on the use of heparin in the prevention of thrombosis and embolism. This heparin was too toxic for general use. Ten years later Charles and Scott¹³ and Murray and Best¹⁴ in Toronto investigated its possibilities and found it effective in the treatment of thrombotic conditions. The use of heparin has many disadvantages: it is expensive, must be given intravenously, and is difficult to control.

In 1941,¹⁵ with the synthesis of dicumarol, the answer to the treatment of venous thrombosis and pulmonary embolism seemed to have been found. Here was an agent that could be produced inexpensively in large quantities and which was effective orally. It changed the coagulation of the blood in the desired way and was easy to control if used intelligently.

Butsch and Stewart¹⁶ tried dicumarol on a small group of patients with no untoward results. They started it forty-eight hours preoperatively so that the patient's prothrombin time was prolonged during and after the operation. No thrombosis occurred in this series. Barker, Allen, and Waugh¹⁷ reported good results while using dicumarol. There was slight bleeding in 4 per cent of their patients postoperatively.

Shapiro and Sherwin¹⁸ and Zucker¹⁹ have also reported favorably on the safety of this drug. On the other hand there has been some adverse comment on the use of anticoagulant in the treatment of thrombophlebitis. The main criticism according to DeBakey has been that the series of investigations is not adequate, nor are the results sufficiently impressive to justify definite statements.

In an effort to evaluate the further use of dicumarol, we subjected a series of surgical patients to a prophylactic course of the drug. At the same time we used this drug in the treatment of cases of venous thrombosis and pulmonary embolism which arose on the surgical services. This experiment extended

from October, 1943, to July, 1944. The technique of administering the dicumarol and the method of performing the prothrombin test to control its use are of such paramount importance that they will be described in detail in the following paragraphs.

METHOD OF ADMINISTRATION

The simplest expression for the coagulation of blood *in vitro* based on the pioneer work of Morawitz, Fuld and Spiro is:

- I. Prothrombin + Ca + thromboplastin = thrombin
- II. Fibrinogen + thrombin = fibrin (clot)

Dicumarol acts by inhibiting the production of prothrombin at its source, namely, the liver.

Dicumarol is a tasteless, odorless white powder which is put up in 100 and 50 mg. capsules. A prothrombin determination is done before administration to find the patient's normal blood level. After this has been established 300 mg. are given. On the following day a prothrombin level is done again, and unless it is markedly prolonged 200 mg. are given. The object is to prolong the prothrombin time to twice its normal value. In other words, if normal is 17 to 20 seconds the therapeutic range would be about 34 to 40 seconds. It is desirable to keep the patient in this range during treatment. Naturally, every person reacts differently to drugs and it is necessary to adjust subsequent doses individually. In many cases the prothrombin time is prolonged rapidly and the prothrombin determination on the third day shows that the patient is in the therapeutic range. Then it is best not to give any drug on that day and see what the prothrombin level is on the fourth day. If still in the therapeutic range, no drug is given on that day either. On the other hand, if the prothrombin time is rapidly becoming shorter and the patients are getting out of the therapeutic range, 100 mg. of dicumarol are given. Other patients will be found who do not reach the therapeutic range with the first 300 and 200 mg. In these cases another 100 mg. are given on the third day and prothrombin observation made daily after that. The important thing in giving the drug is to remember that its effect is delayed and cumulative. It is better to proceed cautiously and give smaller doses than to plunge recklessly ahead. The essential principle, therefore, is not to give any dicumarol until after the prothrombin level has been recorded. When this has been done, given conservative doses, 100 mg. usually after the second day and never more than 200 mg. at a time, sometimes even 50 mg. is enough.

If bleeding should occur, a transfusion of fresh citrated blood plus 60 mg. of water-soluble vitamin K intravenously will raise the prothrombin level promptly.

Salicylates, notably aspirin, should not be given at the same time that dicumarol is being used. The reason for this is that dicumarol can be synthesized from salicylic acid and while the salicylates are only one-twentieth as active anticoagulants as dicumarol, they might produce an unforeseen intensified action if given together.

TECHNIQUE

Thromboplastin.—Rabbit's lungs.

Preparation:

1. Remove lung from freshly killed rabbit (A.Z. rabbits can be used to save expense).

2. Wash lung, to remove blood, for about fifteen minutes in cold running water; blot out excess with filter paper.
3. Cut in small pieces and place in evaporating dish.
4. Place dish in desiccator (drying agent BaO_2); attach to suction apparatus to form a vacuum.
5. Place desiccator in incubator at 37°C . for twenty-four hours (drying process).
6. Remove pieces of lung from desiccator, grind finely in mortar.

Thromboplastin.—

1. Rabbit's lungs (thrombo), 100 mg.
2. Add 5 c.c. of normal physiologic saline solution (.085 per cent).
3. Inactivate for ten minutes in water bath at 57°C .; stir constantly.
4. Remove from water bath, stirring until thrombo reaches room temperature.
5. Add 5 c.c. of CaCl_2 (1.11 gr. to 500 c.c. H_2O); shake thoroughly.
6. Centrifuge for four minutes at 1,800 revolutions; use supernatant fluid.

Obtaining Blood Specimen.—

1. Use 4.5 c.c. of blood to 0.5 sodium oxalate; 1.34 gr. to 100 c.c. H_2O .
2. Centrifuge and remove plasma.

Prothrombin Determination.—

1. Place plasma in water bath kept at a constant 38°C . temperature.
2. In small tubes add 0.2 c.c. of thromboplastin.
3. To thromboplastin add 0.1 c.c. of plasma. Start stop watch immediately, using loop to determine when complete clot is formed; record time of result.

Proper prothrombin determination is very important as the entire success of the administration of dicumarol depends upon the accuracy of the technique. The Wisconsin Research Foundation specifically recommends the use of rabbit's lung instead of rabbit's brain in the preparation of thromboplastin. The activity of the thromboplastin preparation should always be tested on control blood before the daily prothrombin determination is done.

DISCUSSION

From the experimental data, Table I, it can be seen that we treated 102 surgical patients prophylactically with dicumarol in an effort to prevent post-operative thrombosis and pulmonary embolus. Since the statistics show that this condition does not begin until approximately the sixth or seventh post-operative day, it was thought best to start the drug on the third to the fourth

TABLE I. PROPHYLACTIC CASES

DIAGNOSIS	NUMBER OF CASES	AVERAGE TOTAL MG. DICUMAROL	AVERAGE NUMBER OF DAYS IN THERAPEUTIC RANGE
Hernioplasty	37	800	5
Hysterectomy	19	700	6
Appendectomy	21	700	5
Cholecystectomy	3	700	4
Laparotomy	5	700	8
Miscellaneous	17	700	6

postoperative day. In this way the prothrombin time was not prolonged at the time of operation, and a few days were permitted to elapse postoperatively in order that healing might begin. That this time, namely the third or fourth postoperative day, was the most opportune day to administer the drug is shown by the fact that we found neither thrombotic phenomena nor postoperative bleeding.

Tables II and III illustrate the typical cases of venous thrombosis and pulmonary embolism that occurred after 2,591 general surgical and obstetrical procedures carried out during this experimental period. Dicumarol carefully administered in these cases resulted in uniformly favorable results. The thrombophlebitis cleared up promptly and none of the pulmonary emboli caused fatal results.

TABLE II. VENOUS THROMBOSIS

DIAGNOSIS	NUMBER OF CASES	AVERAGE TOTAL MG. DICUMAROL	AVERAGE NUMBER OF DAYS IN THERAPEUTIC RANGE
Hysterectomy	10	840	9
Postpartum	11	900	10
Hernia	3	850	10
Appendectomy	2	700	10
Gastric resection	1	600	12
Cholecystectomy	1	1,400	22
Lobectomy	2	600	8
Fracture of femur	1	1,400	23
Excision of tumor of leg	1	1,000	19
Amputation of leg (diabetic)	1	1,300	25

This latter observation is essentially important as it is well known that 20 per cent of the minor emboli result in death. Extreme care was again observed in the administration and control of dicumarol; consequently, there were no complicating hemorrhages. In acute pulmonary embolism it is proper to administer heparin by vein and start dicumarol by mouth at the same time. This should be done because dicumarol has a twenty-four to forty-eight hours' latent period and it is important to have the coagulation mechanism altered by the heparin until dicumarol takes effect.

TABLE III. PULMONARY EMBOLISM

DIAGNOSIS	NUMBER OF CASES	AVERAGE TOTAL MG. DICUMAROL	AVERAGE NUMBER OF DAYS IN THERAPEUTIC RANGE
Hysterectomy	4	1,090	15
Oophorectomy	1	1,800	17
Hernia	2	1,700	17
Amputation of leg	1	2,100	13
Saphenous ligation	1	1,400	13

Heparin is put up in 10 c.c. vials. One vial is mixed with a 500 c.c. saline infusion and given intravenously at the rate of 20 drops per minute. The blood coagulation time is done every four hours by the tube method. The purpose of the heparin is to prolong the coagulation to three times its normal figure. If normal is five minutes it should be kept at fifteen minutes. This is regulated by increasing or decreasing the rate of flow of the heparin. When the infusion bottle is emptied it is refilled with the same mixture, and this proce-

ture is kept up as long as heparin is needed. When the dicumarol administration is considered to be effective, heparin is stopped.

From our experience we feel that dicumarol is a safe means for preventing postoperative venous thrombosis and pulmonary embolism. Whether it should be used routinely is still a matter of debate. However, we are convinced that it should be given in all cases where thrombotic complications are likely to arise. This will include extensive pelvic operations, operation for abdominal malignancy, and operations on individuals who have previously shown tendency to thrombosis. Naturally, it is the drug of choice when these conditions have developed. From our experience we would further recommend that each hospital intending to use this drug should designate one member of its staff to familiarize himself with the methods of administration and laboratory control. This would guard against harm to the patient and injury to the reputation of an excellent drug.

CONCLUSION

1. Dicumarol is of definite value in the prevention of postoperative venous thrombosis and pulmonary embolism.

2. Dicumarol is the drug of choice in the treatment of thrombotic phenomena.

3. Dicumarol is a safe drug if administered intelligently after careful prothrombin determination.

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RETROGRADE ARTERIOGRAPHY IN THE STUDY OF THE ABDOMINAL AORTA AND ILIAC ARTERIES

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THE pathology of the abdominal aorta has received little attention from the clinicians due to the fact that there was no practical method for its exploration.

Plain radiographs may demonstrate calcification of the walls of the abdominal aorta or its branches, and may show the presence of aneurysms if their walls are calcified; but when calcification is not present or is very slight, plain x-ray investigation is of no practical value.

A method for the radiographic study of the abdominal circulation was described for the first time by Dos Santos in 1929. He proved the value of aortography in the study of a great number of pathologic conditions of the abdomen.*

The difficulty of the technique of the aortography described by Dos Santos requiring blind puncture of the aorta was a stumbling block in the generalization of this method which promised to be so valuable to the clinician. I tried to use Dos Santos' method of "blind aortography" in the course of experiments in the treatment of cancer of the abdominal organs with certain substances that became fluorescent when exposed to x-rays. To avoid the difficulties that arose with Dos Santos' method, I recommended the use of a new technique for the arteriographic study of the abdominal aorta which was presented at the forty-first meeting of the American Roentgen Ray Society, Boston, Mass.† This technique consists essentially in the puncture of the femoral artery at the level of Scarpa's triangle with a trocar through which a rubber catheter is introduced and passed into the iliac artery up to the desired level in the aorta. Through this catheter 25 to 30 c.c. of a 70 per cent solution of diodrast are injected at the rate of 5 c.c. per second. The trocar is then withdrawn, a stitch placed in the adventitia of the artery, and the wound closed. Using the same injection, urograms are taken after the aortography.

In view of the present difficulties to obtain rubber catheters, I was compelled to substitute the aortography by catheterization for the present "retrograde abdominal aortography." In this method the femoral artery is exposed by blunt dissection, under local anesthesia, at the level of Scarpa's triangle and punctured with a trocar 1.5 mm. in diameter. Through this trocar is injected 50 c.c. of a 70 per cent solution of diodrast in two and one-half to three seconds. Tourniquets must be placed at the roots of both lower extremities in order to avoid the passage of the contrast medium into the arteries of the legs. The Trendelenburg position may be required in certain cases. In experiments with dogs I was able to determine in the fluoroscope that the opaque substance had to overcome first the inertia and then the blood pressure when it was injected. It reaches

This work was done at the Cancer Institute with the collaboration of Dr. P. Jimenez and Dr. Gomez Zaldivar.

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*Dos Santos, Reynaldo, Lanas, A. C., and Caldas, J. P.: Arteriography of the Extremities and of the Abdominal Aorta, Paris, 1931, Masson & Cie.

†Farinas, P. L.: Aortography by Catheterization, Am. J. Roentgenol. vol. 46,

a higher level during diastole and descends during systole, entering then into the branches of the abdominal aorta. To avoid changes in pressure when the opaque substance is injected by hand, I have designed an apparatus to maintain a constant pressure and rate of injection. It consists of a pump with a piston which acts upon the embolus of the syringe. The piston works by an air compressor with a regulator and a manometer (Fig. 1).

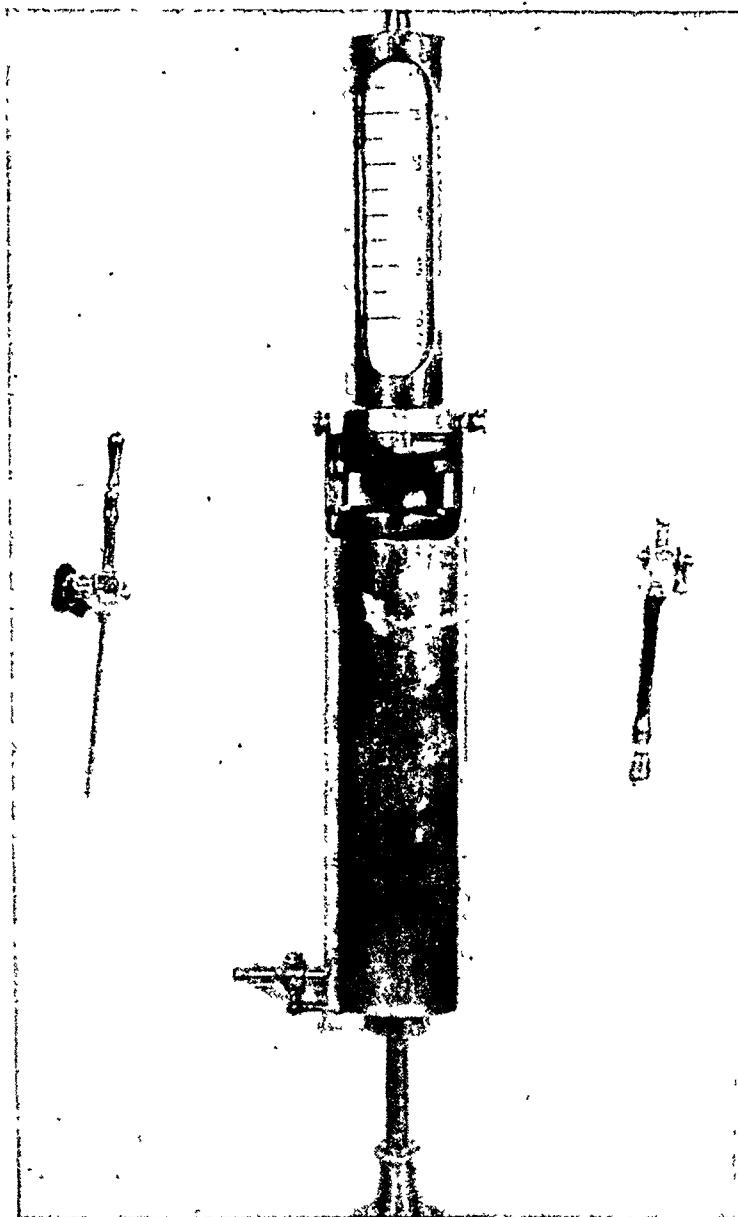


Fig. 1.—Instruments required: One trocar 1.5 mm. in diameter, one 50 c.c. syringe, a flexible rubber tube to connect the trocar to the syringe, a pump with a piston that acts upon the embolus of the syringe.

With a trocar 1.5 mm. in diameter and a constant pressure of fifteen pounds, it is possible to inject 25 c.c. of the opaque substance per second, the speed of injection being modified according to the blood pressure and the vascular condition of the patient. The first plate is taken when 40 c.c. of the opaque substance have been injected and a second immediately afterward, using a fast plate changer (Fig. 2.) When the injection is finished, the trocar

is withdrawn, a stitch placed in the adventitia of the artery at the site of the puncture, and the wound closed. The patient should be given a barbituric the night before, and morphine hypodermically one hour before the injection in order to obtain relaxation and avoid pain.



Fig 2—Patient placed lying down on the plate changer. Everything is ready for the injection

The pathologic changes of the abdominal aorta and of the iliac arteries can be studied by retrograde arteriography. Atheroma is the most frequent lesion that I have encountered in these arteries. The characteristic picture produced by atheroma is due to loss of elasticity of the arteries leading to elongation and dilatation of the vessels, together with stenosis caused by lesions of the intima and secondary calcification. Atheroma is usually found in old age and the lesions are generally seen all along the vessels, being more prominent in the aortic cone and in the iliac arteries (Fig. 3).

Arteriography allows us to study any changes in contour present in both the aorta and iliac arteries clearly showing any strictures or dilatations present. Elongation of these vessels produces vascular kinking that leads to obliteration (Fig. 4). The size of the lumen of the artery and its course permits us to

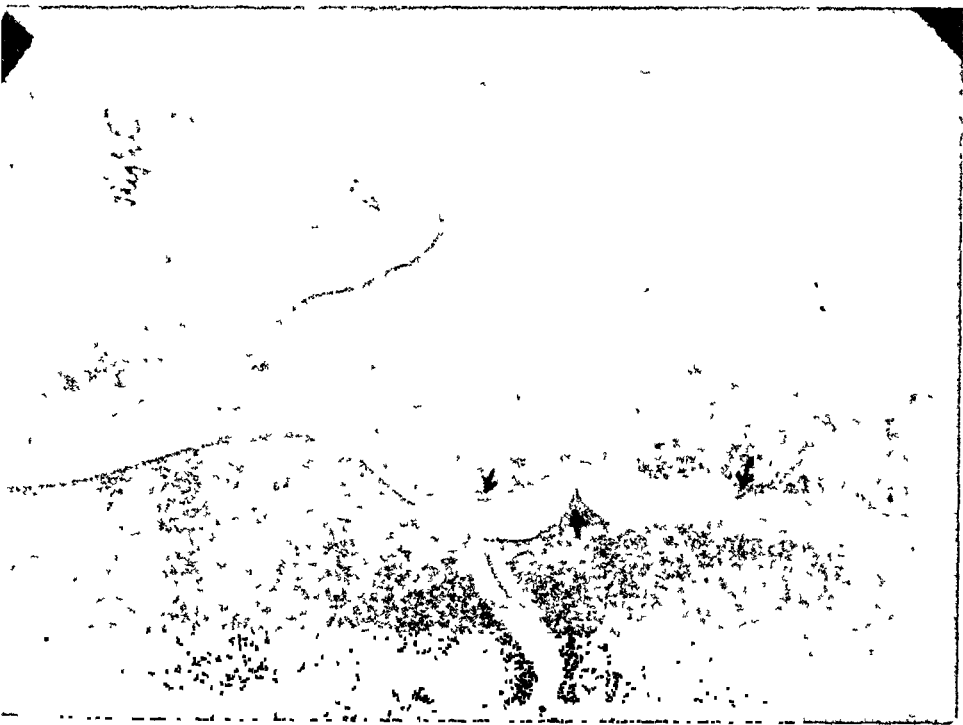


Fig. 4.

Notice the almost complete occlusion at the



Fig. 3.

Fig 3—Advanced atherosclerotic degeneration of the aorta and iliac arteries. Notice the marked calcification and kinking of the arteries.

determine with great accuracy the actual degree of obstruction or calcification. In the presence of aneurysms of the abdominal aorta and iliac arteries, it is possible with this method to determine their localization, extension, the degree of permeability of the aneurysmal sac, the presence of canalization due to organization of blood clots, and the degree of collateral circulation (Figs. 5 and 6).

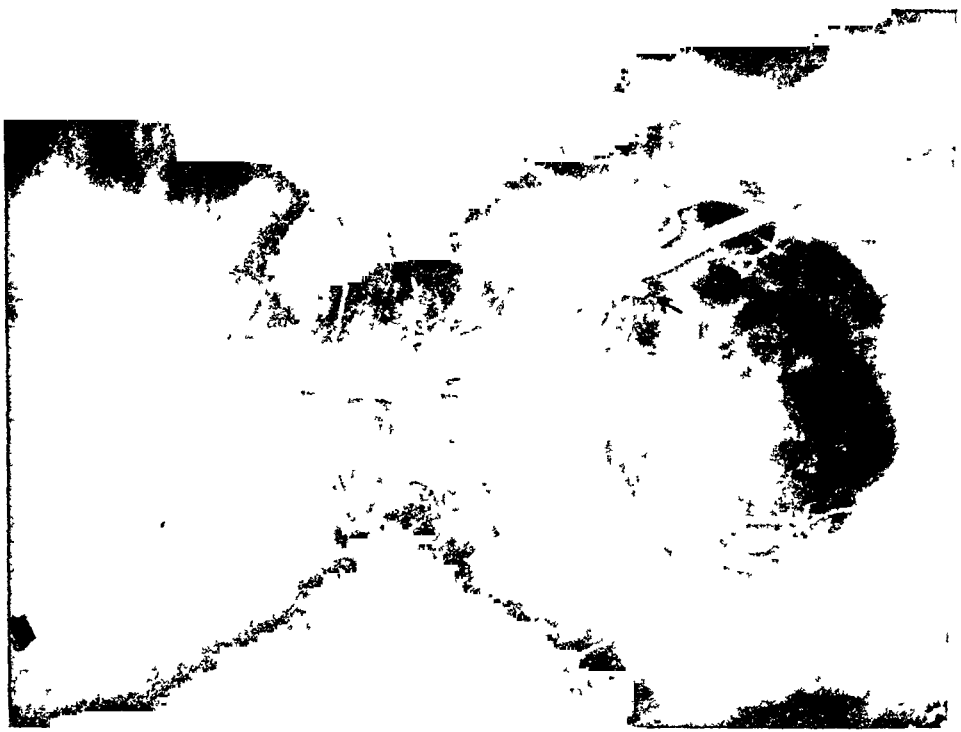


Fig 6
Ligation of both iliac arteries was practiced with marked reduction of



Fig 5.
Fig 5—Canallized aneurysm of the abdominal aorta
aneurysm and complete subsidence of pain
Fig 6 —Aneurysm of the left iliac artery

With this procedure we can also study the characteristics of collateral circulation in cases of complete obstruction of the aortic cone. This collateral circulation takes place by the double anastomosis of the internal mammary with the epigastric artery and the circumflex iliac with the lumbar arteries, thus providing the blood irrigation of the inferior limb.

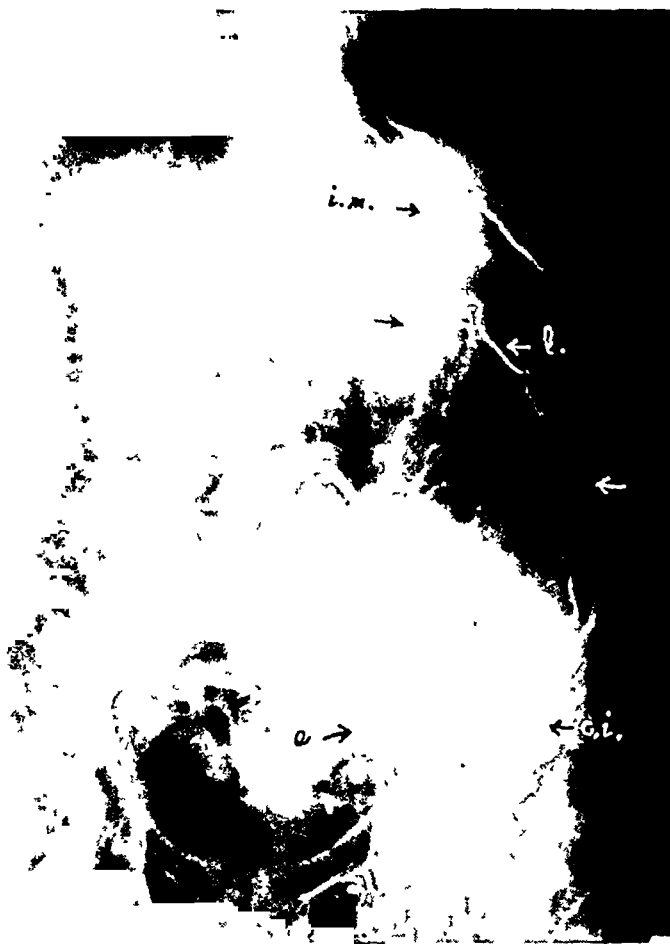


Fig 7.—Complete obstruction of the cone of the aorta and iliac arteries due to advanced atheroma. Notice the two collateral arches; the internal, formed by the epigastric artery (*e*) and internal mammary (*i m*), and the external by the circumflex iliac (*c.i.*) and the lumbar arteries (*l*).

I have had no accidents with this method, even though I have used it in patients in very poor physical condition and with advanced arterial lesions.

The pathologic changes in the visceral branches of the abdominal aorta will be presented in another paper.

BODY FLUID AND PLASMA PROTEIN CHANGES FOLLOWING A SINGLE NONFATAL HEMORRHAGE IN HYPOPROTEINEMIC DOGS

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AN UNDERSTANDING of the pathologic physiology resulting from acute blood loss is of great importance in the management of medical and surgical patients. During recent years renewed interest has become manifest in this subject. In the past the attention of the clinician has been directed principally at the restoration of blood cells and hemoglobin following acute hemorrhage. However, recent studies indicate that restoration of plasma volume and restoration of total circulating plasma proteins are equally if not more important phenomena since these processes help to re-establish the hemodynamics of the peripheral circulation so that any hemoglobin that may remain can carry out its function of transporting oxygen to the tissues.

The results of studies dealing with experimental hypoproteinemia and plasma protein regeneration suggest that there might be a marked difference in the recovery of normal and hypoproteinemic individuals from an acute hemorrhage. Thus, if attention is limited to the changes of the plasma volume and the plasma protein concentration which have been found to occur following a single nonfatal hemorrhage in normal dogs¹⁻⁸ and man,^{9, 10} it would appear that there is a prompt, but gradual, inflow of fluid and plasma protein into the circulation. The initial increase of plasma volume is apparently the result of the addition of fluid relatively low in protein and in from several hours to some seventy hours the plasma volume may be found to exceed the control level. In general, it has been found that the plasma protein (albumin) is restored more slowly than the plasma volume and may still be incomplete at the end of several days. Since there is evidence¹⁰ that after hemorrhage the blood volume is not restored to normal until new plasma protein has been added to the circulation, the present study was carried out in order to compare the spontaneous recovery of normal and hypoproteinemic animals from a single severe nonfatal hemorrhage.

METHODS AND CALCULATIONS

Young adult dogs were used in this study and were placed on a constant diet* for at least seven days before the experiments were undertaken. Hypoproteinemia was then induced in one group of animals by feeding a diet low in protein for a period of four weeks.

The animals were bled 25 per cent of the measured blood volume (estimated from the plasma volume and the hematocrit) without anesthesia, by direct puncture of the femoral artery. Food was withheld for the previous 24 hours and no food or water was allowed for 24 hours after the hemorrhage. After the 24-hour period the animals were again given the respective diets received

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*Purina Dog Chow, Purina Mills, St. Louis, Mo.

before the hemorrhage. One group of the normal and hypoproteinemic dogs was studied before and 4 hours after the hemorrhage. A second group of dogs was studied before and 24 hours after the bleeding. Both groups of dogs were then studied again from 96 to 120 hours after the hemorrhage.

The following determinations were carried out in the control and experimental periods: the plasma volume, the "available (thiocyanate) volume," the total plasma protein and plasma albumin concentrations, and the hematocrit. The methods of determination were the same as those employed in a previous paper.¹¹

The total circulating plasma protein and total circulating plasma albumin were calculated by multiplying the plasma volume in cubic centimeters by the grams of protein per cubic centimeter. The amounts of total plasma protein and plasma albumin removed from the circulation by the bleeding and by the withdrawal of blood for the chemical determinations were estimated by multiplying the volume of plasma withdrawn (c.c. whole blood withdrawn $\times \frac{100 - \text{hematocrit}}{100}$) in cubic centimeters by the grams of plasma protein or plasma albumin per cubic centimeter. The amounts of total plasma protein and plasma albumin restored during the given test period were obtained by deducting from the grams of total plasma protein and plasma albumin removed, the differences of the measured amounts (control and experimental values) of total circulating plasma protein and total circulating plasma albumin, respectively.

EXPERIMENTAL

The average blood changes which were encountered in normal and hypoproteinemic dogs in 4 hours, 24 hours, and in 96 to 120 hours following a single nonfatal hemorrhage have been presented in Tables I to III.

Changes of the Plasma Volume and "Available (Thiocyanate) Volume."—From the data presented in Table I it will be seen that in normal dogs 4 hours following a loss of blood amounting to 25 per cent of the control blood volume, there were decreases of the average plasma volume and "available (thiocyanate) volume" levels. In 24 hours after the bleeding (Table II) the average plasma volume was found to approach the average control level while the average "available (thiocyanate) volume" remained reduced. When the animals were allowed food and water following the 24-hour period and observed again in

TABLE I. AVERAGE BLOOD CHANGES FOUR HOURS AFTER A SINGLE NONFATAL HEMORRHAGE IN NORMAL AND HYPOPROTEINEMIC DOGS*

	NORMAL DOGS (4)		HYPOPROTEINEMIC DOGS (3)	
	CONTROL	4 HOURS	CONTROL	4 HOURS
Body weight (kg.)	12.3		9.2	
Plasma withdrawn (c.c.)	151		130	
Hematocrit (per cent)	40.8	34.9	38.0	33.7
Plasma volume (c.c.)	565	505	492	441
Thiocyanate volume (c.c.)	3,730	3,590	3,620	3,150
Total plasma protein (Gm. per 100 c.c.)	6.17	5.46	4.31	3.81
Plasma albumin (Gm. per 100 c.c.)	3.49	3.15	2.07	1.90
Total circulating plasma protein (Gm.)	34.9	27.8	21.3	16.9
Circulating plasma albumin (Gm.)	19.6	15.7	10.2	8.5
Total plasma protein removed (Gm.)	9.4		5.6	
Total plasma albumin removed (Gm.)	5.3		2.7	
Total plasma protein restored (Gm.)†		2.3		1.2
Plasma albumin restored (Gm.)†		1.4		1.0

*Twenty-five per cent of the measured blood volume drawn. The numbers within the parentheses indicate the number of animals.

†The values were obtained by deducting from the grams of total plasma protein and albumin removed the differences of the measured amounts of total circulating plasma protein and total circulating plasma albumin, respectively.

TABLE II. AVERAGE BLOOD CHANGES TWENTY-FOUR HOURS AFTER A SINGLE NONFATAL HEMORRHAGE IN NORMAL AND HYPOPROTEINEMIC DOGS*

	NORMAL DOGS (4)		HYPOPROTEINEMIC DOGS (3)	
	CONTROL	24 HOURS	CONTROL	24 HOURS
Body weight (kg.)	12.5	11.8	11.4	10.3
Plasma withdrawn (c.c.)	144		144	
Hematocrit (per cent)	43.9	35.2	37.9	31.6
Plasma volume (c.c.)	546	538	550	515
Thiocyanate volume (c.c.)	3,660	3,460	3,820	3,470
Total plasma protein (Gm. per 100 c.c.)	5.91	5.51	4.37	4.02
Plasma albumin (Gm. per 100 c.c.)	3.17	3.09	1.81	1.70
Total circulating plasma protein (Gm.)	32.1	30.0	24.4	20.7
Circulating plasma albumin (Gm.)	17.0	16.3	10.0	8.8
Total plasma protein removed (Gm.)	8.5		6.3	
Total plasma albumin removed (Gm.)	4.6		2.6	
Total plasma protein restored (Gm.)†		6.3		2.7
Plasma albumin restored (Gm.)†		3.8		1.4

*See footnote to Table I.

†See footnote to Table I.

from 96 to 120 hours after the hemorrhage, the average plasma volume and "available (thiocyanate) volume" levels (Table III) were found to be in excess of the average control values.

It will be noted that following a nonfatal hemorrhage in normal dogs the restoration of the plasma volume apparently proceeds promptly. At the end of 4 hours (Table I) the fluid entering the circulation represented, on the average, 60 per cent and at the end of 24 hours (Table II), 94 per cent of the plasma withdrawn. Since no fluid replacement (orally or by vein) was instituted during the latter periods, the fluid entering the circulation represented a redistribution of body water. Although a true evaluation of the changes of the "available (thiocyanate) volume" is difficult, the direction of the changes supports the belief that the fluid entering the plasma was derived chiefly from the interstitial spaces.

The changes of the plasma volume and "available (thiocyanate) volume" which were encountered following the hemorrhage in the hypoproteinemic animals are of considerable interest. As in the normal dogs treated in the same manner, there was evidence of an equally prompt but gradual addition of fluid to the plasma, which was associated with a fall of the "available (thiocyanate) volume" level. Thus, at the end of 4 hours (Table I) the fluid entering the circulation represented, on the average, about 60 per cent and at the end of 24 hours (Table II), 76 per cent of the plasma withdrawn. Observations which were made 96 to 120 hours after hemorrhage (Table III) revealed that the average plasma volume and "available (thiocyanate) volume" levels had returned to the respective average control values.

Changes of the Plasma Protein Concentration and the Hematocrit.—From a perusal of the data presented in the tables it will be noted that there were some similarities in the two groups of animals with respect to the directions of the average changes of the total plasma protein and plasma albumin concentrations and the hematocrit. Thus, in both the normal and the hypoproteinemic animals, decreases of the average values for the total plasma protein and plasma albumin concentrations and the hematocrit were obtained 4 hours and 24 hours following the hemorrhage (Tables I and II). Further, deficits of these constituents from the average control levels still persisted 96 to 120 hours after the hemorrhage (Table III). If the percentage changes from the respective control levels are considered, it will be found that the per cent deficit of the average hematocrit was greater than the per cent deficits for the total plasma protein

TABLE III. AVERAGE BLOOD CHANGES 96 TO 120 HOURS AFTER A SINGLE NONFATAL HEMORRHAGE IN NORMAL AND HYPOPROTEINEMIC DOGS*

	NORMAL DOGS (6)		HYPOPROTEINEMIC DOGS (6)	
	CONTROL	AFTER 96-120 HOURS	CONTROL	AFTER 96-120 HOURS
Body weight (kg.)	12.3	12.0	10.3	9.9
Plasma withdrawn (c.c.)	176		163	
Hematocrit (per cent)	41.8	32.6	37.9	29.0
Plasma volume (c.c.)	568	631	521	539
Thiocyanate volume (c.c.)	3,740	3,900	3,720	3,730
Total plasma protein (Gm. per 100 c.c.)	6.01	5.61	4.34	3.99
Plasma albumin (Gm. per 100 c.c.)	3.24	3.10	1.94	1.75
Total circulating plasma protein (Gm.)	34.1	35.5	22.9	21.7
Circulating plasma albumin (Gm.)	18.3	19.5	10.1	9.4
Total plasma protein removed (Gm.)	10.6		7.1	
Total plasma albumin removed (Gm.)	5.7		3.2	
Total plasma protein restored (Gm.)†		11.8		5.8
Plasma albumin restored (Gm.)†		7.0		2.5

*See footnote to Table I.

†See footnote to Table I.

and plasma albumin concentrations. This observation can be taken to indicate that some protein had entered the plasma during the period of observation. In addition, the per cent fall of the average hematocrit was found to be the lowest at 4 hours after the hemorrhage and the greatest at the end of the 96- to 120-hour period. On the basis of the hematocrit change, therefore, it can be inferred that there was a progressive blood dilution during the period of observation, which supports the findings for the plasma volume previously noted.

Plasma Protein Regeneration.—The differences between the measured amounts of total circulating plasma protein on the one hand and total circulating plasma albumin on the other, deducted from the respective amounts of total plasma protein and plasma albumin removed as the result of the bleeding, were taken to represent the amounts of total protein and albumin which had entered the plasma during the given test periods. Thus, from the data presented in Table I it will be seen that with the bleeding of the normal dogs, an average of 9.4 Gm. of total plasma protein and an average of 5.3 Gm. of plasma albumin were removed. Further, in 4 hours after the hemorrhage, on the average, 2.3 Gm. of total protein and 1.4 Gm. of albumin had been added to the plasma. In other words, about 24 per cent of the average total plasma protein and about 26 per cent of the average albumin removed from the plasma as the result of the hemorrhage were restored in 4 hours. Similarly, in 24 hours after the hemorrhage (Table II) normal dogs were found to have added an average of 6.3 Gm. of total protein (about 74 per cent of the total protein removed) and an average of 3.8 Gm. of albumin (about 83 per cent of the albumin removed) to the plasma. When the observations were carried out 96 to 120 hours after the hemorrhage (Table III), and the animals allowed a normal diet beginning at the end of the 24-hour period, the amounts of total protein and albumin added to the plasma were found to exceed the amounts removed by the bleeding.

A similar analysis of the data obtained on the hypoproteinemic animals revealed that even in the presence of body protein depletion some protein entered the plasma following a single nonfatal hemorrhage. Thus, from Table I it will be seen that in 4 hours after the hemorrhage, on the average, 1.2 Gm. of total protein and 1.0 Gm. of albumin had been added to the plasma. These figures represented a restoration of about 21 and 37 per cent, respectively, of the total plasma protein and plasma albumin removed by the bleeding. Similarly, in 24 hours after the hemorrhage (Table II) the hypoproteinemic animals were

found to have added, on the average, 2.7 Gm. of total protein (representing about 43 per cent of the total protein removed) and 1.4 Gm. of albumin (amounting to about 54 per cent of the albumin removed) to the plasma. When the animals were again allowed the low protein diet at the end of the 24-hour period and the observations repeated 96 to 120 hours after the hemorrhage (Table III) it was found that some additional protein had entered the plasma. Thus, it will be seen that during the period, on the average, 5.8 Gm. of total protein (about 82 per cent of the total plasma protein removed) and 2.5 Gm. of albumin (about 78 per cent of the albumin removed) had been added to the plasma.

DISCUSSION

The data herein reported offer further support to the findings of other workers¹⁻⁸ that following a single nonfatal hemorrhage in normal dogs there is a prompt, but gradual, restoration of the plasma volume and of the total amount of circulating plasma protein. In the present experiments no nitrogen or fluid replacement (orally or intravenously) was instituted for a period of 24 hours after the hemorrhage. During a 4-hour interval in normal dogs the plasma was found to have regained, on the average, 60 per cent of the volume, 24 per cent of the total plasma protein, and 26 per cent of the plasma albumin lost by hemorrhage. Similarly, during a 24-hour period the plasma was found to have regained 94 per cent of the volume, 74 per cent of the total plasma protein, and 83 per cent of the plasma albumin lost by the bleeding. These figures support the view that the initial increase in plasma volume is due to the addition of fluid relatively low in protein and that albumin and globulin are restored at approximately the same rate. It should be pointed out that under similar experimental conditions, Fine, Fischmann, and Frank⁷ found in a 4-hour period normal dogs regained, on the average, 53 per cent of the plasma volume and 30 per cent of the plasma protein lost by hemorrhage.

The data obtained with the hypoproteinemic animals, which were studied in identically the same manner as the normal dogs, are of some interest. Apparently, despite a state of protein depletion as evidenced by the reduced control plasma albumin concentration, the plasma regained during a 4-hour period, on the average, 60 per cent of the volume, 21 per cent of the total protein, and 37 per cent of the albumin lost by the hemorrhage. During a 24-hour period, the plasma regained, on the average, 76 per cent of the volume, 43 per cent of the total protein, and 54 per cent of the albumin lost. Whereas, on the average, the plasma volume was completely restored during a succeeding period of several days when the animals were allowed the low protein diet, the plasma protein restoration remained incomplete. The source of the protein which apparently was added to the plasma is not clear, since in these animals the stores of ready available protein were presumably depleted.

SUMMARY

Determinations of the plasma volume, "available (thiocyanate) volume," total plasma protein and plasma albumin concentrations, and hematocrit were carried out in normal and hypoproteinemic dogs before and following a single nonfatal hemorrhage (25 per cent of the measured blood volume). No nitrogen or fluid replacement was instituted for a period of 24 hours after the hemorrhage. The pertinent findings may be briefly summarized as follows:

1. Following a single nonfatal hemorrhage in normal dogs there was found to be a prompt, but gradual, restoration of the plasma volume and of the total amount of circulating plasma proteins. After the animals had resumed a

normal diet for several days the average levels for the plasma volume and the total circulating plasma proteins were found to exceed the average control values.

2. In normal dogs the initial increase in plasma volume was found to be due to the addition of fluid relatively low in protein. During a 4-hour interval, the plasma was found to have regained, on the average, 60 per cent of the volume, 24 per cent of the total protein, and 26 per cent of the albumin lost by the hemorrhage.

3. The initial increase of plasma volume following hemorrhage was found to be associated with a fall of the "available (thiocyanate) volume." The direction of these changes, when no fluid replacement was instituted, was taken to indicate that the fluid entering the plasma was derived chiefly from the interstitial spaces.

4. The plasma volume was found to increase promptly following a single nonfatal hemorrhage in hypoproteinemic dogs. Observations which were made 4 hours and 24 hours after the hemorrhage indicated that some protein had been added to the plasma. Even though the average plasma volume returned to the control level, after the animals had resumed a low protein diet for several days, plasma protein restoration was incomplete.

5. Despite the fact that the animals were in a state of protein depletion, the plasma regained during a 4-hour period, on the average, 60 per cent of the volume, 21 per cent of the total protein, and 37 per cent of the albumin lost by the hemorrhage. The source of this protein was not apparent.

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INTERSCAPULOTHORACIC DISARTICULATION OF THE ARM

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INTERSCAPULOTHORACIC disarticulation is a term used to denote the removal of the entire arm and shoulder. This includes the scapula, the outer two-thirds of the clavicle, and all attached muscles and fasciae.

The operation was first done by Ralph Cumming of the Royal Navy in 1808. Dixie Crosby of New Hampshire introduced it in America in 1836. Paul Berger of France wrote an exhaustive monograph on the subject in 1887 and gave the operation its present name. The older books of surgery describe it accurately; however, modern texts devote very little space to it, because they aver it is too radical and is rarely indicated. It is our purpose in this paper to define the indications for the procedure, to describe its technique, and to call attention to the importance of this old operation under modern diagnostic and surgical methods.

According to Pack and associates there were twenty-nine recorded interscapulothoracic amputations until 1881, the pre-Listerian era, with an operative mortality of 38 per cent. Berger reduced this to 10.4 per cent. Buchanan analyzed the 141 reported operations up to 1900. Pack and his associates studied an additional 180 reported cases and added 31 of their own. We therefore have a record of 381 patients upon whom the operation has been performed to date. Undoubtedly this is but a small fraction of the actual number done. In Buchanan's group the mortality of the operation was 11.3 per cent. In the collected series of Pack and his co-workers it was 5 per cent and in their own 31 cases there was none. We are reporting an additional 5 cases without operative mortality. In tabulating our findings we have followed the outline suggested in previous studies so that pertinent data may be assembled in a uniform manner.

INDICATIONS FOR THE OPERATION

Interscapulothoracic disarticulation is indicated in the treatment of the following conditions:

Soft tissues

1. All carcinomas of the hand or forearm or arm with metastases to the axilla as determined by lymph node biopsy
2. All proved carcinomas of the arm involving the humerus or shoulder joint, or any of the shoulder muscles
3. Axillary tumors adherent to the vessels and nerves, which cannot be excised locally
4. Extensive trauma which is irreparable
5. Large ulcerating, infected, and painful axillary growths even though metastases are present; pain alone in neoplasms with metastases not an indication; can be remedied by chordotomy or posterior rhizotomy

Bone

1. Sarcomas of the humerus clavicle or scapula
2. Usually though not invariably sarcoma of the forearm

Most patients included in these groups have had local excisions or less radical amputations. It would be well to consider this procedure as the treatment of choice at the outset. This would greatly enhance its curative possibilities.

MERITS OF THE OPERATION

The operation is well conceived. It permits a correct anatomic approach and a complete excision of the morbid anatomy. The blood supply is controlled first. This is a fundamental principle in any extirpative procedure because it reduces operative bleeding. Moreover, in this instance it prevents blood stream dissemination which may result from the loosening of neoplastic cells which have invaded the veins. For this reason we clamp the artery, then tie the vein without raising the arm to empty it of blood. Littlewood's method of interscapulothoracic disarticulation is by a posterior approach. It may be useful in very obese patients or in those with large tumors in front.

The disarticulation permits the complete excision of all anatomic lymphatics and lymph nodes, all related muscular and fascial planes, and all involved axillary tissue, together with the related bones. This may be done as a unit operation with less blood loss than in a radical mastectomy. The skin flaps are usually adequate so that skin grafts are ordinarily unnecessary.

The mortality rate of this radical operation is no greater than for ordinary amputations of the upper arm. Therefore, aside from the disfigurement and inconvenience produced, there are no objections to its use. Certainly these are inconsequential objections, when compared with the additional chances for cure. If a portion of the arm must be removed, then the inconvenience is not much greater and the disfigurement, though unsightly, may be rectified by proper shoulder pads.

TECHNIQUE

Our method is essentially that of Berger with slight modifications of various authors, including our own.

Ether anesthesia by the open-drop method is employed. The patient is placed on the edge of the table with sandbags under the ipsilateral vertebral margin. The arm, chest, neck, and back are surgically prepared and the forearm is covered with sterile towels which are held by a sterile bandage so that the extremity may be moved in any direction.

The primary incision is made parallel with and directly over the clavicle (Fig. 1). The sternocleidomastoid muscle is partially divided from its clavicular origin and the lateral two-thirds of the clavicle are subperiosteally resected. (Berger suggested the middle third, Le Conte the entire clavicle.) By inserting the finger beneath the pectoralis major, the operator may safely separate this muscle from its clavicular attachment. Here the cephalic vein is tied and divided. The subclavius muscle and the overlying periosteum are divided transversely in line with the medial edge of the divided clavicle and reflected laterally (Fig. 2). The anterior incision is carried downward medial to the coracoid process (Kocher). Care must be taken not to injure the dome of the pleura on either side and the thoracic duct on the left.

With this exposure the vascular supply may be clearly identified and controlled. The transverse scapular and transverse cervical veins are tied and

divided before their junction with the external jugular. Next the transverse scapular (suprascapular) artery, a branch of the thyrocervical trunk, is divided between ligatures. It lies anterior to the subclavian artery and is separated from it by a process of the deep cervical fascia which binds the tendon of the posterior belly of the omohyoid muscle to the scapula and first rib.

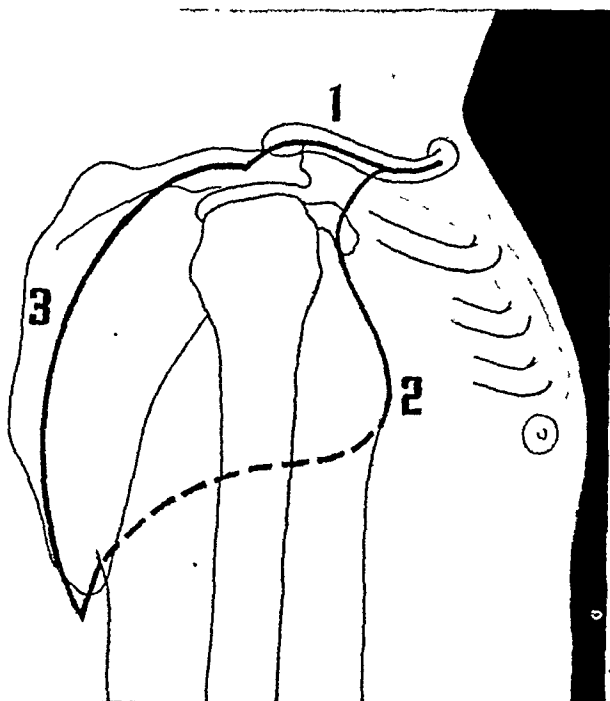


Fig. 1.—Lines of incisions for interscapulothoracic disarticulation. The numbers indicate the order in which the dissections are made.

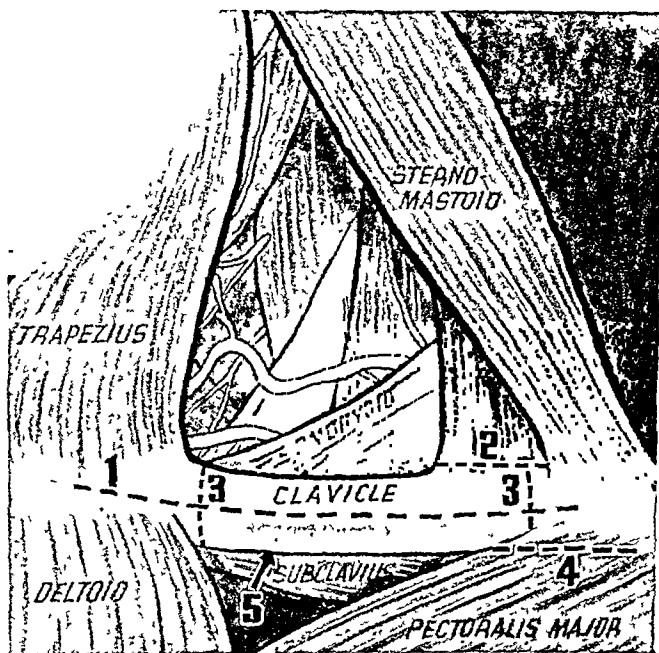


Fig. 2.—Diagram illustrating the anatomy of the subcutaneous structures. 1, Incision in the periosteum of the clavicle; 2, division of sternomastoid muscle from its clavicular origin; 3, subperiosteal removal of the lateral two-thirds of the clavicle; 4, separation of the pectoralis major muscle from the clavicle; 5, severance and lateral reflection of the subclavius and its overlying periosteum in line with medial edge of divided clavicle.

When this muscle is traced upward, the transverse cervical artery (another branch of the thyrocervical trunk) is encountered medial to this muscle. It is tied and divided. The artery usually divides into an ascending (superficial cervical) and descending (posterior scapular) branch when it reaches the anterior border of the trapezius. Occasionally the ascending branch arises from the thyrocervical trunk whereas the descending branch comes directly from the third portion of the subclavian. In this case the former is called the superficial cervical artery, whereas the latter is termed the transverse cervical artery. It is this branch which is divided between ligatures in such anomalies (Fig. 3).

The subclavian vein lies anterior and slightly inferior to the artery. It is carefully dissected loose from the artery, which is clamped. The vein is triply tied with heavy silk and divided between the two lateral transfixed ligatures (Fig. 4). The artery is then tied with a simple ligature. Lateral to this, two transfixed ties are introduced and the vessel is divided between them.

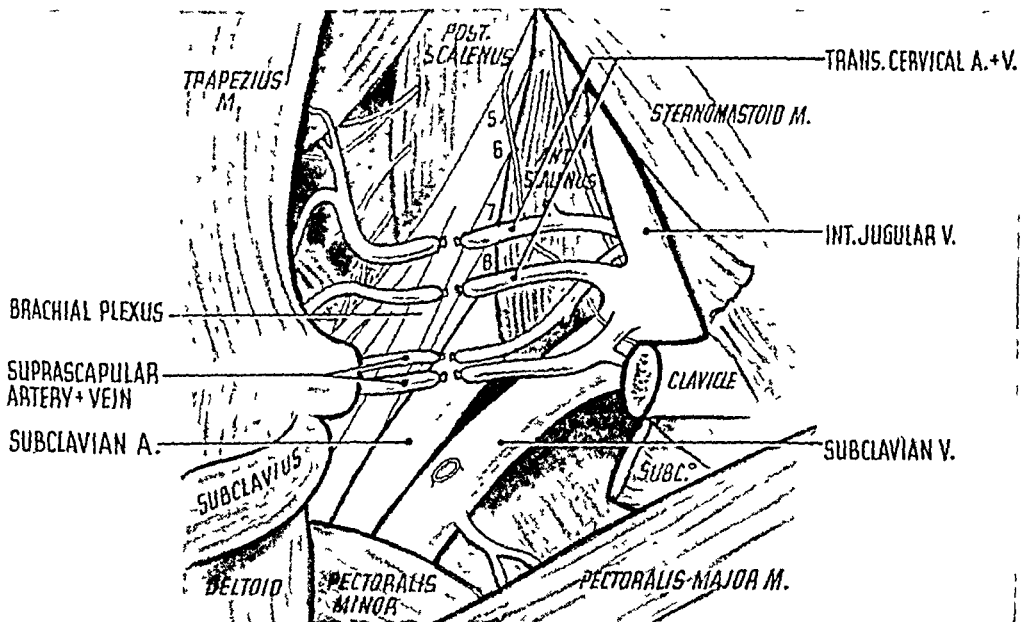


Fig 3—Diagram of the deep anatomy. The transverse cervical and transverse scapular arteries and veins have been divided between ligatures

Up to this point the arm has not been moved because of the possibility of dislodging malignant cells by the manipulation. It is usually recommended that the arm should be elevated and all blood drained. We feel that it is better to lose the small amount of retained blood than to risk the dislodgment of neoplastic cells.

The anterior incision is carried downward along the pectorodeltoid groove to the upper axilla where it is continued posteriorly. The skin flaps are mobilized and the pectoralis major and minor and serratus anterior muscles are divided from their attachments to the ribs. The nerves of the brachial plexus are tied and divided with a sharp knife. They are not injected with 95 per cent alcohol. We have found that the incidence of amputation neuroma is not reduced by this procedure and phantom pain is more apt to occur.

The arm is now held across the body and the posterior incision is made along the borders of the scapula. The muscles divided beginning above the acromion process are the trapezius, omohyoid, levator scapulae, rhomboideus

minor and major, and latissimus dorsi. The teres major and minor, subscapularis, supra- and infraspinatus are removed with the arm (Fig. 5).

Skin flaps are brought together without tension. One small Penrose drain is inserted through a stab wound in the dependent flap. All of our wounds have healed per primam.

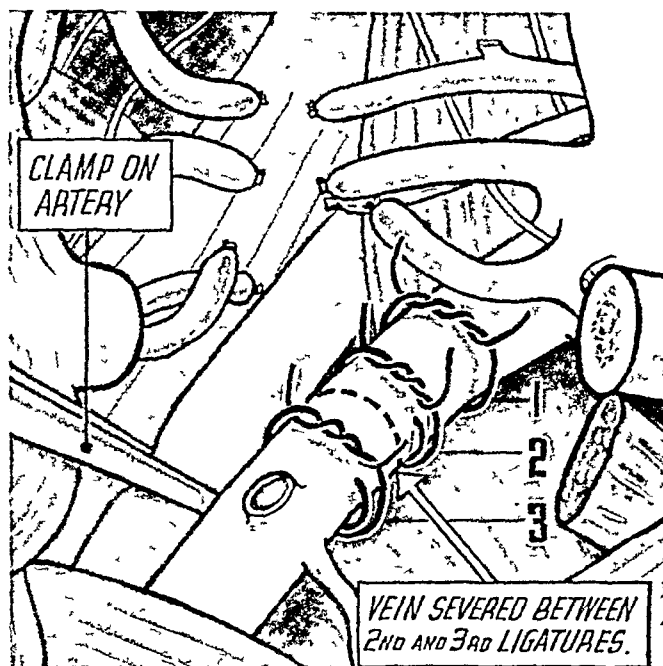


Fig. 4.—Method of vascular control; the subclavian artery has been clamped, the vein is tied with large silk ligatures. 1, A simple tie; 2 and 3, transfix ligatures. The subclavian artery is then handled in a similar manner.

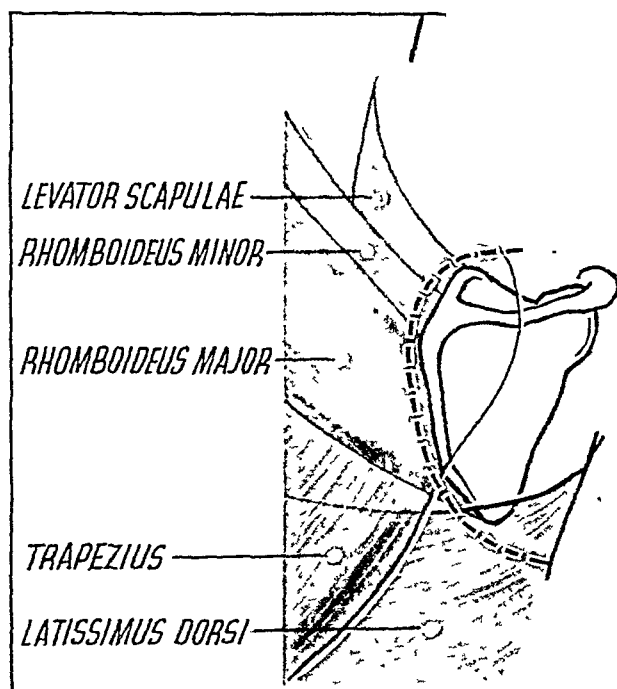


Fig. 5.—Line of posterior incision. The arm has been moved across the chest displacing the scapula laterally.

Blood loss in this procedure is surprisingly small. The operation is well borne with a minimum degree of shock. Patients may sit up in bed within twelve hours and in a chair in twenty-four hours.

COMPLICATIONS AND SEQUELAE

Hemorrhage may occur due to tearing of the vein at operation, slipping of a ligature, or erosion by a malignancy which when removed leaves a hole or a devitalized area in the vessels. We have not encountered such complications. Pack and his associates reported a case in which the subclavian vein was accidentally opened and air audibly aspirated into the vein. Hemorrhage was great but was controlled by compressing the vein with a finger against the first rib. The patient developed the symptoms of shock; he was given a blood transfusion and recovered. The danger of air embolism is real, but is probably exaggerated except in the pulmonary veins. In this instance the bolus of air is carried directly to the left heart where it may easily be sent to the brain, producing an immediate fatality. In the rest of the venous system the air is carried to the lungs where it is less apt to cause serious effects although these have been reported. It must require a large amount of air or a peculiar set of circumstances to produce any alarming results.



Fig. 6.—Clinical photograph (J. B.) showing large carcinoma of right hand. There had been previous attempts at removal. Axillary metastases were present.

Shock may result from the operation, but if the patient is properly prepared this should not occur even in old people.

“Phantom limb” with slight pain was observed in one of our patients (W. C.) This persisted for fourteen months but has now disappeared. The pain was referred chiefly to the dorsum of the hand. This was the site of the large and painful carcinoma (Fig. 7). Amputation neuroma with severe pain occurred in another patient (B. S.). The divided nerves had been injected with 95 per cent alcohol after ligature. Pain persisted during the remainder of the patient’s life, a period of twelve months. Since local injection of procaine into the neuroma did not benefit the patient, excision of the lesion was not attempted. These pains may be due to local irritation of end bulb neuromas or a projection from the sensory areas in the cerebral cortex. The best prophylaxis is, first and foremost, as little handling of the brachial plexus as possible. Second, division of the nerve trunks with a sharp scalpel at a high

TABLE I. INTERSCAPULOTHORACIC DISARTICULATION OF THE ARM

CASE	DATE OF OPERATION	AGE, SEX, COLOR	DURATION OF SYMPTOMS	PREVIOUS OPERATIONS	LOCATION OF PRIMARY LESION	METASTASES AT THE TIME OF OPERATION	HISTOLOGIC TYPE	TYPE OF OPERATION	X-RAY THERAPY		CAUSES OF DEATH		DURATION OF LIFE AFTER OPERATION	COMMENTS
									PRE-OPERATIVE	POST-OPERATIVE	METASTASES	RE-CURRENCE		
O. S.	6/ 5/39	12 yr., F, White	1 yr.	Biopsy osteosarcoma	L. humerus upper $\frac{1}{3}$	None	Osteolytic osteogenic sarcoma	Berger	200 kv.	None	Lungs	No	7 mo.	Auto accident 2 yr. before
M. G.	10/29/41	15 yr., F, Negro	11 mo.	Biopsy fibrosarcoma	R. humerus upper $\frac{1}{3}$	None	Osteolytic osteogenic sarcoma	Berger	200 kv.	200 kv.	Lungs, vertebrae, brain, right ovary	No	8 mo.	Post-mortem examination
B. S.	9/12/43	64 yr., M, White	3 yr.	Biopsy	R. axilla	None	Fibrosarcoma of right axilla	Berger; nerves injected	None	None	Brain, lungs, vertebrae	No	12 mo.	Severe pain in brachial plexus
J. B.	5/26/43	67 yr., M, White	14 yr.	Biopsy hand and axillary nodes	R. hand	Extensive to axilla	Squamous-cell carcinoma of hand and axillary nodes grade III	Modified Koehler; no nerve injection	200 kv.	None	No	No	1 yr. 7 mo.	No phantom pain; no recurrence (See Fig. 6)
W. C.	6/ 9/43	74 yr., M, White	14 mo.	Biopsy of hand, epitrochlear and axillary nodes	L. hand	Extensive to epitrochlear and axillary nodes	Squamous-cell carcinoma of hand, epitrochlear, axillary nodes	Modified Koehler; no nerve injection	200 kv.	None	No	No	1 yr. 6 mo.	Phantom pain until 9/18/44, no pain now; no recurrence

level so that they will not be caught in the granulation tissue and scar of the wounds.

If "phantom limb" is due to the persistence of preoperative pain at the site of the primary growth, then early operation should be helpful. The cause of these pains is not definitely known and the large array of operative procedures offered for their cure is proof of this fact.



Fig. 7.—Clinical photograph (W. C.); recurrent carcinoma of left hand.

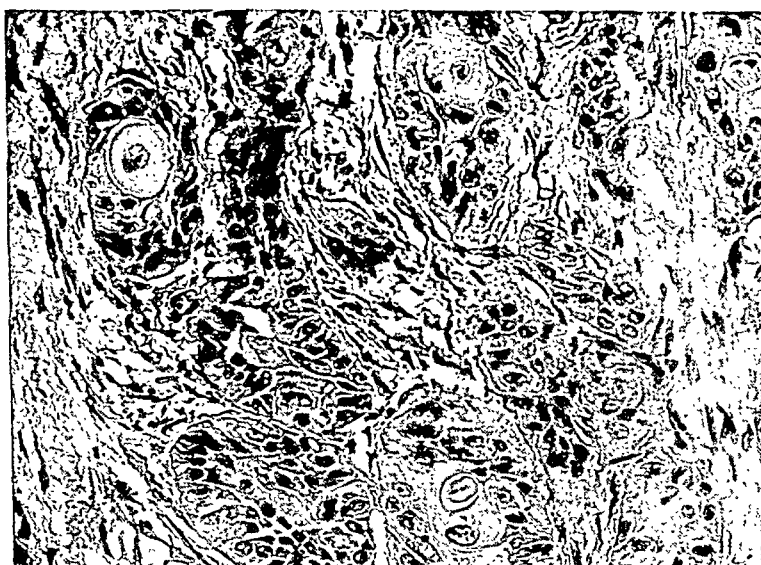


Fig. 8.—Axillary lymph node photomicrograph (W. C.); note complete replacement of lymphoid tissue by carcinoma cells and epithelial pearls.

RESULTS AND CONCLUSIONS

A summary of our cases is given in Table I. Our series is too small to draw any definite conclusions. It is also difficult to evaluate the larger series of Buchanan prior to 1900 because of possible errors in diagnosis.

The 31 cases reported by Pack and his associates are clearly presented. We feel that future studies should be summarized in like fashion so that accurate statistics may be gathered.

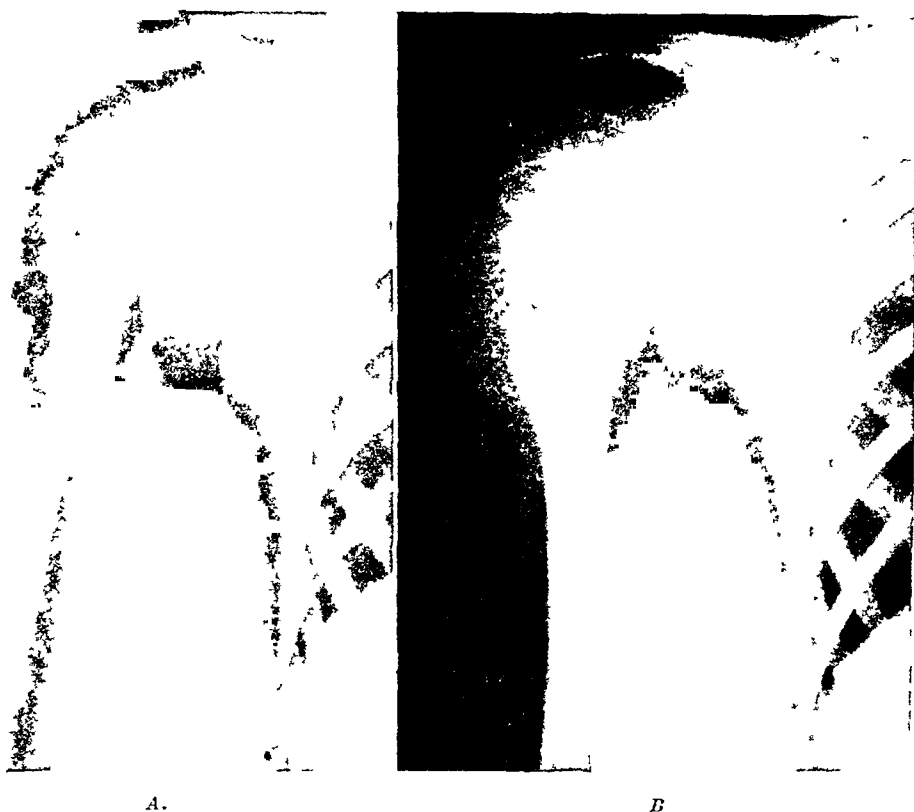


Fig. 9.—X-ray photograph (O. S.) showing osteogenic osteolytic sarcoma of humerus *A*, The bone destruction is clearly seen; *B*, soft tissue changes



Fig 10—The disarticulated arm shown in Fig. 9.

From the experience of others and from our own observations we have drawn the following conclusions.

1. The operation may be safely done.
2. It may be done at any age. The youngest was 12, the oldest 74, average 48 years.
3. Soft tissue growths gave better results than lesions in bone. The former were in the older group and were carcinomas.
4. Symptoms were present from eleven months to three years. Average duration was fifteen and one-half months.
5. All patients had biopsies before operation. Four had one or more attempts at local extirpation.
6. Lymph nodes with metastases were present in the two cases of squamous-cell carcinoma. Metastases could not be demonstrated by x-ray in the cases of sarcoma at the time of operation (Fig. 7).

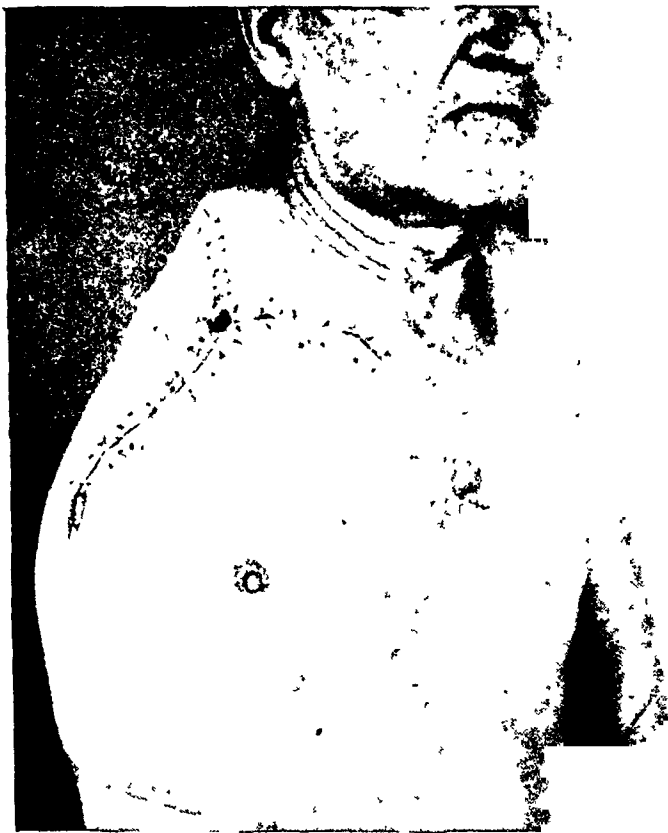


Fig. 11—Clinical photograph (J. B.) showing scar ten days after operation. The wound has healed by first intention

7. X-ray treatment was used preoperatively in four of our patients and postoperatively in one. The two surviving patients received preoperative x-ray therapy only. The value of this is unsettled although we feel that it should be used preoperatively with the idea that it may lessen the chance for metastasis and local recurrence. In radiosensitive or infected growths it may reduce their size, thereby facilitating complete extirpation.

8. None of our patients had local recurrences. The three deaths occurred from internal metastases. They were all patients with sarcoma.

9. The surviving patients are two men with squamous-cell carcinoma of the hand and axillary node metastasis, one, aged 67 years, alive and apparently

well nineteen months and the other, aged 74 years, alive and well eighteen months after the operation.

10. The end results of interscapulothoracic disarticulation are encouraging. Available statistics though meager prove that the operation offers a chance for cure in cases ordinarily considered hopeless.

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Original Communications

LATERAL CERVICAL (BRANCHIAL) CYSTS AND FISTULAS

A CLINICAL AND PATHOLOGIC STUDY*

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THE great variety of lesions which may occur, the difficulty in differential diagnosis, and the hazards of operative procedures in a field compact with important and vital anatomic structures make cervical lesions worthy of study. Interest in cervical lesions has been stimulated by the controversy concerning the origin of many of the congenital cysts and sinuses of the neck. This controversy has made the embryologic development important in the study of these lesions.

If the etiology of congenital lesions of the neck were understood completely, the terminology could be placed on a less confusing basis. In 1832, Ascherson¹ thought he recognized a close relation of the branchial apparatus to the cysts and sinuses which appear on the lateral surface of the neck anterior to the sternomastoid muscle. In 1864, Heusinger² introduced the term "branchial fistula." Senn,³ in 1884, wrote that the terms previously used to designate these tumors were "branchial cysts, dermoid cysts of the sheath of the internal jugular vein, deep-seated atheromatous tumors, tumors of branchial clefts, hydrocele colli congenita, hygroma colli and atheromatous cysts of lymphatic glands." Senn considered the designation of them as "branchial cysts" as the most appropriate.

In 1912, Wenglowski⁴ questioned whether these cysts and sinuses originated from the branchial apparatus. Frazer⁵ objected to use of the word "branchial" because he said these abnormalities were not of branchial origin and had nothing to do with the branchiae. In order to avoid commitment to a theory of origin, many observers have begun to classify these lesions as lateral cervical cysts and sinuses. Frazer preferred to designate them as "vestigial" and there is little doubt but that his term is a most appropriate one. In this study the various terms will be used interchangeably with no implication as to etiology. It is felt that "branchial" has been used so extensively in the literature and has been so well fixed in the minds of medical men that an attempt to discontinue its use will result only in confusion.

Matas,⁶ Senn,³ Christopher,⁷ Carp and Stout,⁸ Hyndman and Light,⁹ Bailey,¹⁰⁻¹² Baumgartner^{13, 14} and others have made excellent contributions to

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the clinical aspects of this subject and innumerable cases have been reported in the literature. Data on a large series of cases from one source have never been reported, however, so it seemed appropriate to analyze and study the cases in which operation was performed at the Mayo Clinic, for, as Baumgartner¹⁴ has noted, "a fundamental knowledge of the subject is not generally held."

EMBRYOLOGY OF THE STRUCTURES OF THE NECK

In the second week of intrauterine life, five depressions occur in each lateral wall of the primitive pharynx. These depressions or outward projections are known as the pharyngeal pouches and are lined by the pharyngeal entoderm. Concomitant with the outpouching of the pharyngeal entoderm, five indentations appear in the ectoderm. These indentations have been designated the "branchial or pharyngeal grooves." Each pouch is opposed by the corresponding groove so that entoderm and ectoderm are in apposition. The mesoderm is pushed aside by the encroaching ectoderm and entoderm with the result that five or six bars or arches make their appearance. In fish these arches are separated by clefts but in man only the pouches and grooves intervene. Each arch contains a basis of cartilage, a vascular arch, nerves, and muscle elements.

The first and second arches are the mandibular and hyoid arches. They grow more rapidly than their companion arches and override the latter in a telescoping process; the second arch comes in contact with the body wall behind the fifth groove and covers the second, third, and fourth grooves. The space thus formed is known as the cervical sinus. It is an enclosed pocket of ectoderm which normally disappears during the second month of intrauterine life.

In the fourth week of intrauterine life the human embryo has no neck. The cephalic prominence is bent so that the heart reaches forward almost to the first arch. The arches from above downward become shorter and the medial ends lie farther and farther apart. The result is a triangular area with the apex cephalad. This is the mesobranchial field of His.¹⁵ From the embryonic visceral arches, their pouches and grooves, the greater part of the neck is derived.

It is well known that as the primitive ventral aorta enters the pharynx, it immediately divides into the right and left ventral aortic roots. From these roots branches (aortic arches) pass upward in the branchial arches and terminate in the dorsal aortae which run backward and unite to form the dorsal thoracic aorta. In fish these aortic arches persist, and, with their capillary network, absorb the oxygen from the water which passes through the gills.

In man, however, this condition is transitory and further alterations ensue. The first and second aortic arches disappear but the facial artery and the lingual artery mark the anterior ends of those arches, respectively. The third aortic arch remains as the first part of the internal carotid artery and the fourth on the right forms the first and second stages of the right subclavian artery. On the left side the fourth aortic arch gives origin to that part of the arch of the aorta which lies between the carotid and the entrance of the ductus arteriosus, and later becomes the ligamentum arteriosum.

From the first groove the external auditory meatus is derived, and the first pouch gives rise to the eustachian tube and tympanum. The tympanic membrane probably is derived from the cleft membrane. The first or mandibular arch grows more rapidly than the others and divides into two portions,

a superior or maxillary and an inferior or mandibular portion. The former gives rise to the upper jaw and the lateral parts of the upper lip and the cheeks; the inferior portion becomes the lower jaw, the lower lip, the region of the chin. This arch contains a rod of cartilage, known as Meckel's cartilage, which gives rise to the intracartilaginous bony structures, the sphenomandibular ligament, the malleus, and incus.

It has been noted that the remaining grooves become covered by the hyoid (second arch) operculum and participate in the formation of the cervical sinus. From the second pouch the angle of the tonsil arises. The second or hyoid arch gives rise to the styloid process, the styloid ligament, the stapes, and the lesser cornu of the hyoid bone.

The pharyngo-thymic duct arises from the third pharyngeal pouch while the body of the hyoid bone and the posterior part of the tongue have their origin in the third arch. The parathyroid glands are derived from the third and fourth pharyngeal pouches. The thyroid ducts, anlage of the lateral lobes of the thyroid gland, are derived from the fourth pharyngeal pouch. The thyroid cartilage is developed from the fourth arch while the cricoid and arytenoid cartilages and rings of the trachea probably represent the fifth and sixth arches.

It has been pointed out that each arch has its nerve and this nerve supplies the muscles of the arch, the pharyngeal lining, and groove recess of the arch. In fact, the embryonic origin of the muscles of the arches is identified by the nerve supply of the muscles. As the cephalic prominence rises from the thoracic wall the neck increases in length, the arches descend, and the muscular elements migrate. This migration is not always regular, however, and the greatest irregularity is found in the muscles of the second arch which pass upward into the face and scalp (occipitofrontalis muscle and muscles of expression) and downward into the neck (platysma muscle). This migration accounts for the wide distribution of the seventh nerve, the nerve of the second (hyoid) arch. The nerve of the first arch is the third division of the trigeminal nerve; that of the third arch, the glossopharyngeal nerve; that of the fourth arch, the superior laryngeal branch of the vagus; and of the fifth and sixth arches, the inferior laryngeal branch of the vagus.

ETIOLOGY

There is no general agreement concerning the etiology of lateral cervical cysts and fistulas. Although we have reviewed all the theories, space will not permit an exposition of them. It was thought by Ascherson¹ that the lesions result when the cleft boundaries fail to fuse. It was pointed out by His¹⁵ that the partition between the pharynx and the outside groove is thin and, under abnormal circumstances, may tear and give rise to a fistula. Rabl¹⁶ studied the second arch intensively and considered the level of the second furrow the logical place for a fistula to enter the pharynx. Carp and Stout⁸ concluded that nearly all types of branchial anomalies were understandable on this basis. Wenglowski,⁴ whose work has been given much acclaim, was of the opinion that lateral cervical cysts and fistulas were vestiges of the thymic duct.

MATERIAL AND METHOD OF STUDY

In the files of the Mayo Clinic, and acceptable for this study, were the case records of 319 patients who had been operated upon for lateral cervical cysts or fistulas from 1908 to October, 1938, inclusive. A few records could

not be included because the patients did not submit to operation and the diagnosis, therefore, was not confirmed. Others were discarded because of insufficient data. The surgically removed specimens were available in 287 of the cases. In the remainder of the 319 cases, the specimens had been misplaced, discarded, or had deteriorated to such a degree that they were of no value. In each of these cases the specimen had been examined and described by the surgical pathologist, however, so that complete pathologic information was known. In this study we did not include any case in which pathologic material was not available or had not been adequately described. The preauricular sinuses and cervical appendages, both of which are thought to have etiologic factors similar to those of lateral cervical cysts and fistulas, were not included.

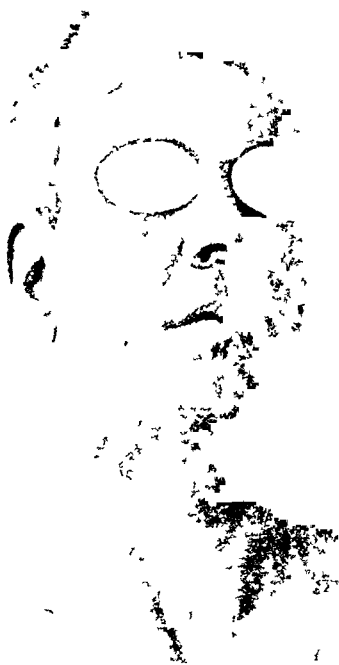


Fig. 1.—A lateral cervical cyst presenting in the most common location, just below the angle of the jaw.

In most of this report no attempt is made to segregate the cysts and the fistulas, but in our discussion of clinical findings the number of cysts and fistulas encountered in our series is listed. Not infrequently a cyst is associated with a fistula, and far too frequently a cyst is converted into a fistula by the surgeon's scalpel. It is not always possible to state with certainty that a lesion in question was primarily a fistula or a cyst.

That lateral cervical cysts and fistulas are comparatively rare is attested by the fact that only small numbers of patients with these conditions have been seen at large medical centers.

HISTORY AND SYMPTOMS

By far the most frequent symptom is a painless swelling in the neck (Fig. 1). In 259 of the 319 cases studied, the chief complaint was the presence of

a mass. Even in a part which is almost constantly exposed, as is the neck, the cyst may reach large proportions before it is observed. This fact is undoubtedly explained by the gradual increase in the size of the cyst, as occurred in 117 of the cases studied (Table I). Rapid enlargement was observed in only

TABLE I. PREDOMINANT SYMPTOMS

SYMPTOMS	CASES
Gradual enlargement of cyst	117
Symptoms preceded by or associated with upper respiratory infection	61
Draining sinus	58
Pain	53
Intermittent swelling	39
Rapid enlargement of cyst	26
Dysphagia	17
Drainage in pharynx, or peculiar taste	16
Fever	14
Husky voice	6
Pressure	6
Retraction on swallowing	6
Bulging or fullness in floor of mouth or pharynx	5

twenty-six cases. Variation in the size of the cyst is mentioned by many observers and was reported by thirty-nine of the patients in our series. This phenomenon is explainable if the cyst can empty its contents into the pharynx through a small opening. It probably is caused more frequently by the physiologic activity of the lymphatic structures contained in the wall of the cyst, however.

The association of cervical cysts with infections of the upper part of the respiratory tract is striking. Sixty-one patients in the group under consideration stated that the recognition of the presence of their lesions was preceded by, or associated with, infections of the upper part of the respiratory tract.

A draining sinus was the complaint in fifty-eight cases. At birth the external end of the fistula may be only a dimple in the skin and several years may elapse before mucoid fluid escapes, or only a drop or two of clear fluid will escape at intervals. Some of the patients gave a history of the formation of a mass in the neck, which, when pressed on, disappeared after drainage of a considerable quantity of fluid from the sinus. The majority of the fistulas are produced by the ill-advised incision of a cyst. A cyst treated by incision may continue to drain continuously until completely removed surgically, or the opening may heal only to break down and drain again. One of the patients included in this study found that the intake of food, especially liquids, caused an increase in the drainage from the fistula. Fortunately, pressure phenomena are not often present but occasionally, because of the swelling, obstructive symptoms with respiratory embarrassment may develop.

Pain is present in only a small percentage of cases of lateral cervical cysts and fistulas. Of 319 patients, only 53 had discomfort and frequently this was extremely mild. When a cyst assumes large proportions, it impinges on adjacent structures and may give rise to a sensation of pressure, drawing, or fullness and may cause dysphagia and huskiness of the voice.

A cervical cyst or fistula is occasionally said to produce symptoms of a systemic character. Inflammation is the most common complication associated with these lesions and it is certainly conceivable that an infected cyst or sinus could be the focus of infection.

The length of time patients defer seeking medical advice after the appearance of disease continues to amaze physicians. The duration of symptoms in

TABLE II. DURATION OF SYMPTOMS IN 319 CASES OF LATERAL CERVICAL CYSTS AND FISTULAS

DURATION OF SYMPTOMS (YR.)	PATIENTS	PER CENT
Less than 1	100	31
1 to 9	162	51
10 to 19	32	10
20 to 29	9	3
30 to 39	3	1
40 to 49	3	1
Not known	10	3

cases of cervical cysts and fistulas varies tremendously (Table II). In studying our 319 cases it was found that symptoms had been present for less than one year in 100 cases and from one to nine years in 162 cases. Three patients stated that they had had symptoms for more than forty years! In twenty-five cases the lesion was present at birth.

History of Trauma.—The history of a blow occasionally has been given as a factor in the production of a cyst and such a history may have medicolegal aspects. A few cases have been reported in which blood was found in the cyst. Case 1 is of some interest.

CASE 1.—A man, aged 22 years, stated that a cyst on the right side of the neck was first observed when he was 8 years old. It had gradually increased in size. Just before registration at the clinic the patient had been struck on the neck by a ball. The cyst immediately became sore and tender and a constant ache occurred. The cyst covered the anterior third of the clavicle. It was completely excised. On pathologic examination the cyst was found to be a typical branchial cyst and was filled with blood clots.

CLINICAL FEATURES

Lateral cervical cysts and fistulas appear with equal frequency in the two sexes. Of the 319 patients, 171 (53.6 per cent) were males and 148 (46.4 per cent), females. The ages varied from extreme youth to old age but 117 patients were in the third decade of life. The youngest patient was aged 4 months and the oldest was 84 years of age.

In 140 cases (44 per cent) the lesion was on the left side; in 172 (54 per cent), on the right side, and in 7 (2 per cent), on both sides. Two hundred thirty-nine of the lesions were cysts and eighty were fistulas. There were forty external fistulas, thirty-one complete fistulas, and nine internal fistulas.

In practically all cases the cysts were anterior to the sternomastoid muscle. By turning the head and placing the muscle on the stretch this relationship can be demonstrated to better advantage (Fig. 1). The muscle may be thinned out over the cyst, or, more rarely, a portion of the cyst may be present on each side of the muscle. The size of the cyst varies from that of an olive (2.5 by 1.5 cm.) to the size of a large orange (about 10 cm. in diameter) but the actual size of the cyst cannot always be detected clinically.

Fluctuation can be elicited in many cases. This sign cannot be relied on, however, for in large, tense cysts, those with thick walls, those with cheesy contents, and in deep-seated cysts, fluctuation is not easily obtained and the cyst may be mistaken for a solid tumor. Nearly all the cysts transmit light poorly. Unless there has been considerable reaction in or around the cyst wall, it is movable and not fixed to the skin or underlying structures. It presents a regular outline and the skin over it is smooth.

Possibly the close relationship existing between cyst or fistula and the vagus nerve accounts for the occasional production of a spasmodic cough when a probe is inserted.

TABLE III. ANATOMIC POSITION OF CYSTS AND EXTERNAL OPENING OF FISTULAS

SITE OF CYSTS AND EXTERNAL OPENING OF FISTULAS	CASES	PER CENT
In upper part of neck, at angle of jaw	234	74
In middle part of neck	26	8
In lower part of neck	4	1
Above sternoclavicular joint	41	13
Not stated	14	4
Total	319	100

The external opening of a branchial fistula is practically always in that part of the neck bounded by the midline medially, the sternomastoid muscle laterally, the level of the hyoid bone superiorly, and the suprasternal notch inferiorly (Table III). Usually the opening is along the anterior border of the sternomastoid muscle; the external opening of fistulas which have been present since birth is found most frequently just above the sternoclavicular articulation. Not infrequently swellings develop around the external openings.

It is generally agreed that the internal opening, when present, is in the supratonsillar fossa, although one writer¹⁷ recently has reported finding the opening in the tonsil. In only a small percentage of the cases, however, can the internal opening be demonstrated.



Fig. 2.—A lateral cervical cyst following the injection of lipiodol. This procedure is advocated by some clinicians as a means of distinguishing these cysts from tuberculous abscesses.

It is said that the rising of the external fistulous opening with deglutition indicates a complete fistula. According to Semken,¹⁸ complete fistulas are present in one-third of the reported cases. Commonly the fistulous tract is palpable as a firm cord. It is possible to demonstrate the course and extent of the fistula by injecting the tract with a radiopaque substance and making a roentgenogram (Fig. 2). One hundred twenty-six patients had had previous operations (Table IV).

TABLE IV. TREATMENT AND OPERATIVE PROCEDURES PREVIOUSLY EMPLOYED

PROCEDURE	CASES	PER CENT
Incision and drainage of cyst (from 1 to 50 procedures per case)	75	24
Tonsillectomy	35	11
Röntgen rays, radium, or ultraviolet light	31	10
Attempted excision	25	8
Aspirations	14	4
Dental extractions	7	2
Iodine injection, arsphenamine, leeches (1 each)	3	1
Total cases in which previous operations had been performed for cysts and fistulas	126	40

DIFFERENTIAL DIAGNOSIS

In many instances the correct diagnosis of lateral cervical cyst and fistula must be made by the surgical pathologist. By thorough examination and by careful utilization of all the information at his command, the clinician can distinguish branchial cysts and fistulas in a high percentage of cases from numerous other lesions which appear in the neck. The correct diagnosis was made clinically in 181 of the 319 cases encountered at the Mayo Clinic. In other instances the diagnosis was suggested but other possibilities were given preference.

Tuberculous Lymph Nodes.—Branchial cysts and fistulas are most frequently confused with cervical tuberculous lymph nodes. Carp and Stout⁸ stated that the close resemblance of the contents of the cysts to cold abscesses caused the incorrect diagnosis in one-half the cases. In addition to frequently having a similar appearance, the contents of the two are also sterile. Bailey^{10, 11} stated that tubercle bacilli are found in only 10 per cent of tuberculous glands. This fact, together with Bailey's finding of a branchial cyst which was also tuberculous, renders the search for, and finding of, tubercle bacilli of little value, and inconclusive. In many instances enlarged lymph nodes are attached to the wall of the branchial cyst but usually the mass formed by tuberculous glands is more irregular and the skin may be adherent. The absence of enlarged lymph nodes elsewhere and the absence of other evidences of tuberculosis should be considered as evidence in favor of the diagnosis of branchial cyst.

Bailey,¹⁰ Wangenstein,¹⁹ Greene and Greene²⁰ and others have stated that the most accurate method of identifying a branchial cyst is by aspiration and examination of the fluid in the cyst. The presence of cholesterin crystals in the fluid is positive evidence of a cyst. In only one instance did Bailey¹⁰ fail to find cholesterin crystals. In that case some substance had previously been injected into the cyst which made the contents unsuitable for examination. Wangenstein¹⁹ said that the high lipid content of the fluid from a branchial cyst frequently imparts a shimmer or yellowish sheen to it when it is placed in a basin. Tuberculous pus does not have these characteristics.

Tumors of the Carotid Body.—Branchial cysts are far more common than tumors of the carotid body, which are rare. It is noted that tumors of the carotid body move laterally but not vertically and that pulsation usually is transmitted. Their position is similar to that usually assumed by branchial cysts. It is important to distinguish between these two lesions before the patient is anesthetized because the operative procedure for removal of the tumor of the carotid body is of great magnitude and the prognosis is grave.

Cystic Hygroma.—The lesion of cystic hygroma is first noticed in infancy. It is usually diffuse, loculated, and translucent, and most commonly is situated

in the lower half of the neck. A branchial cyst, however, is nearly always well circumscribed, unilocular, and opaque, and is situated in the upper part of the neck more frequently than in the lower part.

Suppurative Cervical Lymphadenitis.—Acute inflammation of a branchial cyst or fistula may be difficult to distinguish from suppurative cervical lymphadenitis. The history of swelling or of drainage from a sinus preceding the inflammation may give the clue to a correct diagnosis.

Dermoid Cysts.—Dermoid cysts are said to be more superficial tumors than branchial cysts and their location is not constant. Apparently they are also rare.

Lipomas.—The fatty tumors, lipomas, are frequently lobulated, but may simulate branchial cysts. They yield no fluid on aspiration, however.

Neurofibromas.—Neurofibromas may be confused with branchial cysts. Their firm, solid consistency and their limited mobility owing to fixation to the deeper structures of the neck, however, are important features in differential diagnosis.

Hemangiomas and Lymphangiomas.—Deep-seated venous and lymphatic angiomas are occasionally mistaken for branchial cysts. When pressure is made on these tumors their contents are evacuated.

Chronic Retropharyngeal Abscess.—It may sometimes be difficult to distinguish between the swelling caused by chronic retropharyngeal abscess and branchial cyst. Coakley²¹ noted the possibility of confusing the two and a case was encountered at the clinic in which the condition was treated at first as an abscess by drainage but because of the mucous character of the drainage the lesion was later removed and proved to be a cyst.

FAMILIAL TENDENCY

For many years it has been noted that branchial fistulas may occur in several members of the same family. In twenty-one of 100 collected cases, Fisher²² found an hereditary influence, and in three generations of the same family Ascherson¹ found eight persons affected with branchial fistulas. Cases in which a strong familial tendency was present have also been reported by Cates,²³ Vaughan,²⁴ Tilley,²⁵ Hyndman and Light,⁹ Carp and Stout,⁸ and others. A woman seen at the clinic had bilateral cervical fistulas. Her father, paternal grandfather, brother, and a cousin on her father's side all had bilateral cervical fistulas. In addition, another brother had a branchial appendage.

CLASSIFICATION

Various classifications have been suggested for lateral cysts and fistulas. Possibly one of the oldest, as well as one of the most useful, is that of Bland Sutton.²⁶ He classified these lesions as follows: (1) The complete fistula, which is the prototype, has an external opening and an opening in the pharynx; (2) the external fistula has an external opening in the skin but ends internally as a cul-de-sac; (3) the internal fistula has an opening in the pharynx but the fistula ends externally as a cul-de-sac; this type is rarely recognized and is probably the rarest; Heusinger² thought some pharyngeal diverticula were of this nature; (4) the cyst has a closed canal both internally and externally but an unobliterated segment remains in the neck.

Bailey has divided lateral cervical cysts into four types, according to their relationship to the surrounding structures, as follows:

The cysts of type 1 are fairly superficial, are at the anterior border of the sternomastoid muscle and beneath the cervical fascia. The cysts of type 2 lie on the great vessels. The wall of the cyst may be adherent to the jugular vein. This is said to be the type most commonly encountered. In this type, and also in type 1, the spinal accessory nerve is in a constant relation posteriorly. The cysts of type 3 extend to the lateral wall of the pharynx. A large cyst may pass through the bifurcation of the carotid artery. It may extend up as far as the lateral mass of the atlas and even to the base of the skull. The cysts of type 4 are columnar epithelium-lined cysts near the pharynx. They probably produce no symptoms.

The contents of the cysts and the lining epithelium form the basis for some classifications. Hyndman and Light⁹ were of the opinion that an adequate and simple classification is: (1) branchial cleft epidermoid cysts and (2) branchial cleft mucous cysts.

PATHOLOGY

Gross Pathology.—The size of lateral cervical cysts varies from less than 1 cm. to more than 10 cm. in diameter. Of the cysts in which size was recorded, 122 had a diameter greater than 5 cm. and the diameter of some of these was more than 10 cm. In eight the diameter was from 1 to 2 cm., in thirty from 2 to 3 cm., in fifty-one from 3 to 4 cm., and in forty-nine from 4 to 5 cm.

A cyst is usually longer than it is wide, and is shaped like an egg or lemon (Fig. 3a). Some, however, are nearly spherical. There frequently is a suggestion of lobulation. The entire cyst is surrounded by a loose connective tissue through which course veins and small arteries. In eighty-eight of the specimens examined lymph nodes were attached to the walls of the cysts.

The thickness of the cyst wall varies tremendously. Carp and Stout⁸ found this variation to be from 1 mm. to 1 cm. Some of the walls are as thin as tissue paper and collapse into a small heap as soon as they are punctured, allowing the contents of the cyst to escape. The walls may be nearly 1 cm. thick, however, and when the contents of such a cyst are evacuated the specimen maintains its shape. The thin walls are opaque and glistening while the thicker walls are darker.

The inside of a cyst wall usually presents a far more interesting picture (Fig. 3b). The thinnest walls may be perfectly smooth, but when those a little thicker are held in a proper light very small projections may be seen. The epithelial lining of some of the cysts is pinkish and may be easily stripped from the underlying tissue. This lining may be smooth or wrinkled, simulating skin which has been immersed in water. On nearly every lining membrane there are wartlike projections or papillomas. These vary in size and in number; they may be barely visible, but are occasionally from 5 to 6 mm. in diameter. They may be few in number or numerous enough to cover the entire cyst wall (Fig. 4a).

Thin septa may traverse the cyst wall and divide it into irregular compartments (Fig. 4b). Frequently these septa converge to the same place on the cyst wall. The septa have the appearance of fibrous cords or contractures, and give the cyst wall a trabeculated appearance. Papillomas may be present also, but rarely on the septa.

The gross and microscopic appearances of a fistula are shown in Figs. 5 and 6 a and b.

Microscopic Pathology.—Typically, the microscopic study of a lateral cervical cyst or fistula reveals a stratified squamous epithelium which lies on a

lymphoid base, the latter in turn being surrounded by a layer of loose connective tissue. In different specimens the layers vary in thickness and in other respects (Figs. 7 *a* and *b*, 8 *a* and *b*, and 9). It is probably advisable to discuss each component separately.

In 263 of the 287 specimens of cysts and fistulas examined histologically at the clinic the lining was of squamous-cell epithelium. In eighteen cases it was columnar and in six cases both columnar and squamous-cell epithelium



Fig. 3.—*a*, External appearance of a moderately large cyst; the loose connective tissue, the blood vessels, and the lobulations are shown; *b*, interior of a cyst showing the wrinkling of the epithelium and the wartlike projections.

were found (Fig. 9). Bailey¹² has said that a fistula is lined by columnar ciliated epithelium unless inflammation has been present. This observation is not substantiated by the findings in our series. In some fistulas the epithelium is of columnar type, but in the majority it is of the squamous-cell type.

In addition to finding the structure of branchial cysts constant, Gilman²⁷ also found that the number of cell layers in the lining of squamous-cell epi-

thelium varies at different areas. This finding coincides with the observations made in our study, but when the epithelium was found to be thick at one area, it was usually only a trifle less thick at the thinnest area. In other words, there was a tendency to maintain approximately the same number of cell layers throughout. In 176 instances the epithelium was found to be of average or moderate thickness; in seventeen it was definitely thick, and in ninety-four thin.

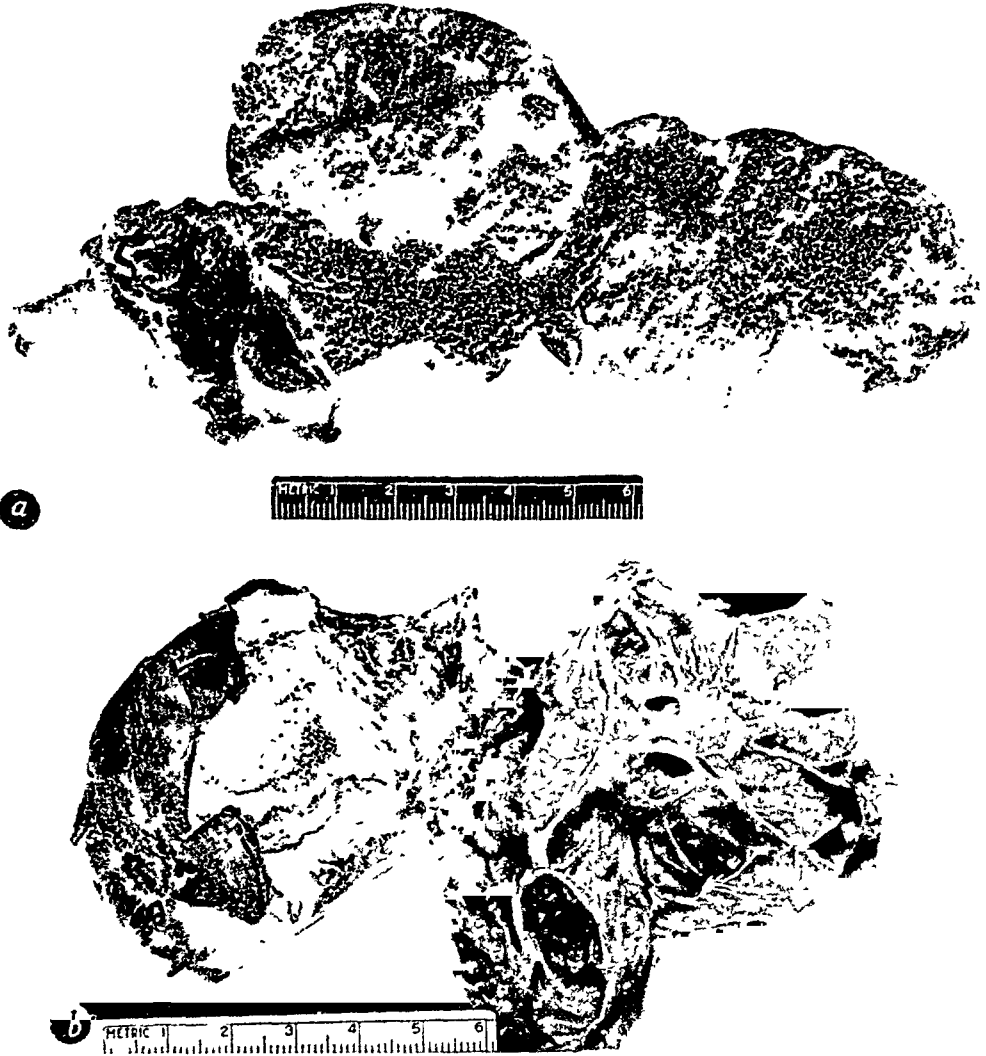


Fig. 4.—The interior of a large cyst; *a*, the wall is thick; the entire inner surface is covered by confluent wartlike projections of the squamous epithelium; *b*, the cordlike bands which divide the cyst into trabeculations.

It is true that in the majority of instances the epithelial layer rests on a base of lymphoid tissue (Fig. 7*b*), as was observed in 185 of the specimens examined. In ninety-one specimens the epithelium rested on connective tissue (Fig. 8*b*), however, and in eleven cases it rested on both lymphoid and connective tissue. Germinal follicles were present in the lymphoid band in 137 of the 287 specimens examined (Fig. 8*a*). Gaston²⁸ said that follicles are such a constant finding that they are of diagnostic importance, a statement not supported by our study. In 119 of our specimens the lymphoid tissue was scant, in 138 moderate, and in 30 thick.

The supporting layer of connective tissue also varies greatly in its width, as seen in the cross section. In fifty specimens in our series it was thick, in 139 average or moderate, and in ninety-eight thin. It sometimes is penetrated deeply by lymphoid tissue which seems detached from the main lymphoid band. Blood vessels are numerous and around many of them are accumulations of round cells. In the event of acute inflammation this supporting layer of connective tissue becomes engorged with leucocytes. Serous glands are occasionally found in this layer and muscle fibers are occasionally present. In 276 specimens studied in our series chronic inflammation was present in the connective tissue layer, in three inflammation was acute, and in ten no inflammation was found.



Fig. 5.—Bilateral complete cervical fistulas removed through a single collar incision.

Contents.—The epithelium lining the cyst or fistula retains its capacity to form the products of epithelial metabolism. These products are discharged into the cyst or fistula and compose the contents or the drainage. Hyndman and Light⁹ found a thick, transparent, mucoid, sticky fluid in the cysts and

At the level of the hyoid bone it turns inward and proceeds toward the pharynx. Apparently, some fistulas pass over the carotid sheath and some pass between the external and internal carotid arteries, for there is disagreement on this point. The fistula then crosses over the hypoglossal nerve, passes under the posterior belly of the digastric muscle, over the glossopharyngeal nerve, under the styloglossus muscle, and to the pharynx near the tonsil.

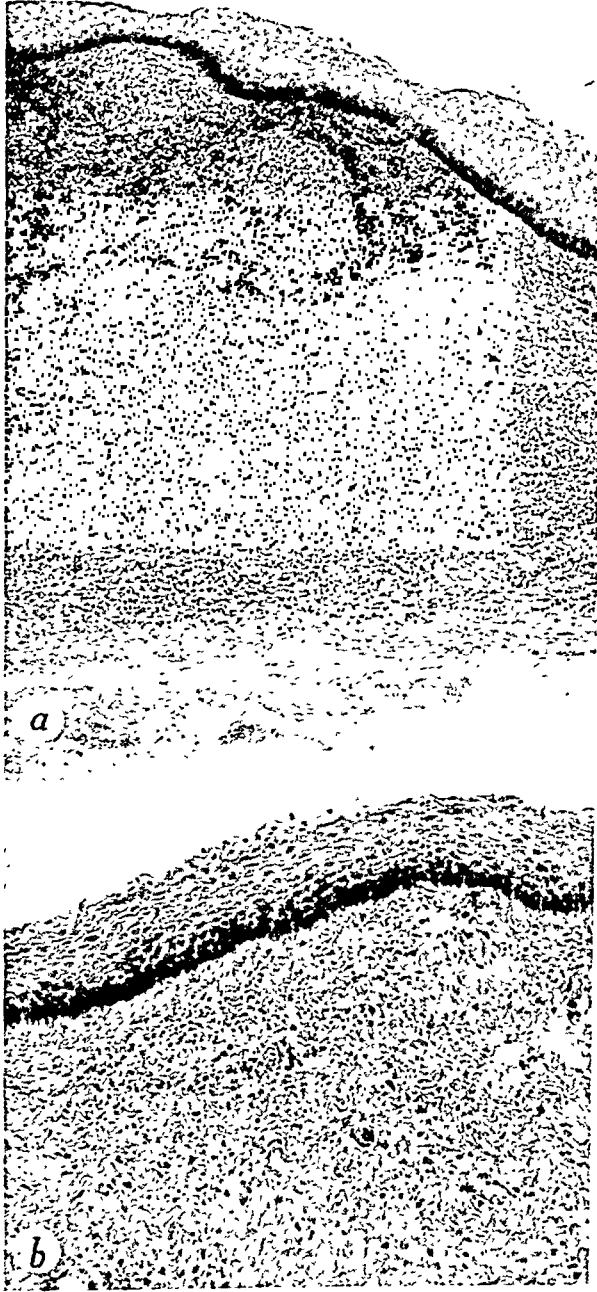


Fig. 8.—Cyst wall; *a*, which shows a secondary follicle in the lymphoid tissue ($\times 90$); *b*, in which the stratified squamous epithelium lies directly on the connective tissue.

Several methods of dealing with the internal portion of the fistulous tract have been described. In the procedure described by von Hacker³³ the medial end of the fistula is cut and cauterized. Through this stump a probe is cautiously passed into the pharynx. The end of the probe is made fast to the

cut end of the fistula and by gentle traction on the probe through the mouth the fistula is inverted into the pharyngeal cavity, where it is ligated and cut off short. If the fistula cannot be dissected to the pharynx a technique described by Koenig³⁴ may be employed. By bringing the distal end of the fistula into the buccal cavity in front of the tonsil the secretions are caused to drain into the mouth instead of externally. Both the von Hacker and the Koenig procedures are beautifully illustrated in Christopher's article.



Fig. 9.—Cyst wall which shows both columnar and stratified squamous epithelium ($\times 80$).

It has not been found necessary to invert the stump of the fistula into the pharynx in all cases, just as it is not essential to invert the stump of the appendix in all cases. If the fistula is dissected to the pharyngeal wall, ligated close to the wall, cut and carbolized or cauterized, a good result can be anticipated. This method was employed in thirty-four cases at the clinic (Table V). Ladd and Gross³⁵ did not find it necessary to turn the stump into the pharynx.

It must be emphasized that it is absolutely necessary to remove the entire tract. If a long medial portion is allowed to remain, a complete fistula will have been converted into an internal fistula and the latter may be as annoying as the former.

Removal of a cyst usually offers far less difficulty than excision of a fistula. In the superficial type an incision is made over the cyst in a natural crease in the skin and the cyst enucleated. Those cysts which are in close

TABLE V. OPERATIVE PROCEDURES EMPLOYED AT CLINIC

OPERATIVE PROCEDURE	CASES
Excision	283
Dissection to pharynx and opening demonstrated surgically	34
Drainage instituted	3
Curettage	1

relation to the great vessels may be adherent (Fig. 10). Bailey occasionally found it necessary to divide the sternomastoid muscle and isolate the spinal accessory nerve. This nerve should always be identified. If the cyst is large and exposure cannot be readily obtained, the cyst may be aspirated. Bailey¹⁰ then placed gauze and forceps over the puncture wound and made gentle traction on the cyst wall. Bevan³⁶ stated that if he ever were unable to complete the dissection he thought he would prefer to take a segment of the jugular vein rather than leave part of the wall of the cyst and cauterize. As previously mentioned, in order to effect a cure, it is essential to remove all of the secreting epithelium.

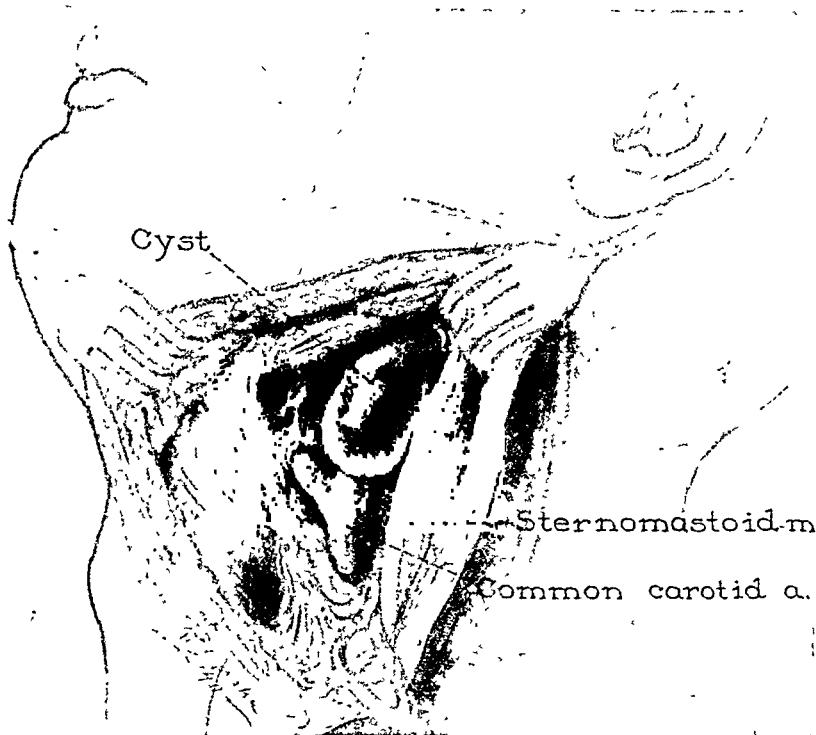


Fig. 10.—Location most commonly assumed by lateral cervical cysts and the relations to the great vessels.

RESULTS OF TREATMENT

Two deaths followed 321 operations performed at the clinic on 319 patients in a period of about thirty years, an operative mortality of 0.63 per cent. Gaston²⁸ reported one death in twenty-nine cases, an operative mortality of 3.4 per cent. One fatality in our series was that of a child, aged 1 year, who had not been well since birth. An attempt to remove a large cervical cyst had previously been made. The cyst protruded into the pharynx and interfered with respiration. In spite of the child's poor condition, extirpation of the cyst was considered advisable. Operation was performed Jan. 3, 1912. The cyst weighed 15 Gm. and measured 4 by 2.5 by 2.5 cm. On the fifth postoperative day the patient died of bronchopneumonia.

The second patient who died was a man, aged 49 years, who had syphilis. He had a large cyst which had enlarged rapidly and in the few weeks before admission it had caused dyspnea on exertion. The cyst occupied the submaxillary and submental regions. The floor of the mouth bulged and the

larynx could not be seen. Feb. 25, 1924, the cyst was excised. In twenty-four hours the patient had difficulty in breathing and his voice became throaty. The wound was explored but no evidence of fresh hemorrhage was found. The patient died on the operating table. Death was attributed to edema of the larynx and tissues of the neck.

The final result of operation for lateral cervical cysts and fistulas is gratifying. If we assume that the 147 patients who have not been heard from are well, 309 patients have obtained a satisfactory result. The incidence of recurrence is small.

Late postoperative complications which were caused by injuries to nerves occurred in twelve cases. Apparently, the glossopharyngeal nerve is the nerve most frequently injured since three patients complained of atrophy and deviation of the tongue. Two patients had atrophy of the muscles of the shoulder girdle and two presented Horner's syndrome.

SUMMARY

Congenital cysts and fistulas which appear on the lateral aspects of the neck are referred to as branchial, vestigial, and lateral cervical. There is no unanimity of opinion as to the etiology of these lesions. The work and theory of Wenglowksi,⁴ however, have greatly influenced thought on this subject.

Several members of the same family, and of one or more generations, may be afflicted. Other congenital lesions also are encountered occasionally in cases of lateral cervical cysts and fistulas.

A study was made of 319 cases in which operation was performed for lateral cervical cysts or fistulas at the Mayo Clinic. Specimens for pathologic study or data on pathologic findings were available in all cases. Detailed microscopic studies of specimens were made in 287 cases. Painless swelling was the most frequent symptom. In sixty-one cases the lesions were preceded by, or associated with, infections of the upper respiratory tract. Symptoms not infrequently appeared following tonsillectomy.

In our series patients of both sexes were affected equally. The ages of the patients varied from 4 months to 84 years. The greatest number of patients (37 per cent) were in the third decade. The two sides of the neck were involved approximately equally. The lesions were bilateral in 2 per cent of the cases.

In the great majority of cases the lateral cervical cyst was located in the upper cervical region near the angle of the jaw.

In the complete and internal fistulas the internal opening usually is in the supratonsillar fossa. It is difficult to demonstrate clinically.

Lateral cervical cysts and fistulas must be distinguished from other lesions, especially tuberculous lymph nodes.

These lesions have a distinct pathology and microscopic examination is essential. The diagnosis of branchial carcinoma is probably erroneous. The lesion designated as "branchial carcinoma" is probably secondary to a healed or undiscovered primary lesion in the nasopharynx.

Conservative treatment is indicated in the presence of acute inflammation. Complete excision of the cyst or fistulas is the treatment of choice in the great majority of cases. In experienced hands the operative mortality is low.

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THE USE OF SKIN FLAPS IN THE REPAIR OF SCARRED OR ULCERATIVE DEFECTS OVER BONE AND TENDONS

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DURING the past fifteen years a series of ninety-seven patients has been operated upon with the objective of correcting chronic ulcerative lesions or deep adherent scars by means of skin flaps. In most instances these lesions have been located upon the extremities, but there also have been a few located on the head and body. In all these individuals it was deemed that skin grafts would not give adequate or proper coverage or skin grafts had been tried with ultimate failure, either because they did not "take" or had broken down later.

When a chronic ulcer is immediately over bone or heavy tendon or is surrounded by deep heavy scar, the resultant central ischemia may be such that a subcutaneous tissue provision is necessary to ensure a viable skin covering. When bone or a large tendon is uncovered, or nearly uncovered, and trauma has to be withstood, the addition of both skin and subcutaneous tissue may be obligatory. A skin flap can obtain most of its nourishment circumferentially. Occasionally in civilian life and often in warfare one will encounter a wound which has torn out skin and subcutaneous tissue, exposed tendons or nerves, severed tendons and nerves, or has resulted in loss of bone. In the first instance a thicker coverage than a skin graft may be the better coverage, in the second instance an immediate skin and subcutaneous tissue coverage may be obligatory if one is to preserve tendon or nerve function, and in the latter case skin and subcutaneous tissue are necessary both for coverage and for allowance of further operative procedures when such are contemplated.

One of our main reasons for presenting this group of defects, corrected by means of skin flaps, is to emphasize that often a skin flap can be transplanted with safety and the resultant aseptic denuded base from which the flap was removed covered by a skin graft at the first operation. This makes the procedure one which takes from between two and three weeks to execute, in contradistinction to one in which a series of delayed or tubed flaps are used which takes a matter of a number of weeks or even months. (Ghormley and Lipscomb,¹ four to seven operations, average ninety days' hospitalization.)

METHODS OF SKIN AND SUBCUTANEOUS TISSUE TRANSFER

Before going further with the discussion it might be well to summarize very briefly the various methods of skin flap transfer. Skin flaps may be transferred by the direct or delayed methods, or by means of a direct or intermediate carrier.

Direct Transfer.—In direct transfer the skin flap is elevated from its bed and transferred to its permanent situation at the first operation. This may be done by rotating the skin flap (Hindoo,² 5000 B.C.), by using a member such as the arm for transfer to a more distant location (Tagliacozzi,³ 1597); by sliding the skin flap (French method) and by bringing the member to be covered to the skin flap, as the hand to an abdominal flap or one leg to the other. Direct transfer may be done when the blood supply is sufficient to allow the skin flap to remain viable.

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Delayed Transfer.—The delayed methods which tend to enhance the nutrition of the flap include: (1) raising of the skin flap and simply suturing it back in its bed with or without leaving a bridge pedicle to be cut later (Tagliacozzi,³ 1597 and Blair,⁴ 1921), (2) placing some such material as a skin graft beneath the skin flap with either unipedicling or bipedicling of the flap (Morgan,⁵ of London), (3) tubing of the flap (Filatoff,⁶ 1917 and Gillies⁷ in 1920), (4) the use of an intermediate carrier such as raising a flap from the abdomen and attaching it to the wrist with the ultimate objective of using the arm for distant transfer (Sebileau,⁸ "regional justiposition," 1926), or (5) finally jumping a skin flap end over end. (Roux,⁹ 1854.)

Delayed Transfer Without Tubulization.—When practicing delayed transfer without tubulization of a skin and subcutaneous flap (Blair), the flap is outlined, raised from its bed, and immediately replaced and resutured back in its original position. As a rule, about ten days later the flap is transferred to the site to be repaired. Thus, the flap is transferred as soon as the blood supply to the pedicle has had sufficient time to increase, because of dilatation or possible increase or realignment of the blood and lymph vessels within the pedicle. The disadvantage of the method is the matter of time and the increase in the number of operations. When the blood supply is sufficient there is no necessity for using the procedure. On the other hand, the method may have four advantages. First, by its use, a longer, more narrow, and thinner flap may be obtained than if immediate transfer is made, and second, the flap may be completely outlined in piecemeal fashion, with an interval of a week or two between advancement of the incision of the smaller or the distal pedicle. Third, if the blood supply is still questionable, an interval of time can be allowed for re-establishment of the circulation, after which the flap may be raised from its bed a second time. Fourth, if, after all these methods for establishing an adequate blood supply, the blood supply of the flap still appears to be insufficient, one may leave it in its bed and save the embarrassment of losing the flap.

The Tubed Pedicle Skin Flap or Satchel Handle Flap.—The method (Filatoff, Gillies) consists of making two parallel incisions, after which the skin and all or part of the subcutaneous tissue is raised. The defect is then closed with sutures beneath the flap, or if this is impossible, a skin graft may be used to cover the denuded area. It is possible, but not desirable because of infection and contraction, to allow the bed to remain unclosed and to heal by granulation. The parallel edges of the raised flaps are sutured together so that the flap is thrown in the form of a tube or cylinder with the surface of the skin outward. By this method a greater blood supply is developed in each pedicle. This method has the advantage that an untubed flap, continuous with the distal end of the tubed pedicle, can be raised two weeks or more after the original flap is tubed. If there is any question concerning the blood supply of the distal prolongation, one may outline it, separate it, and suture it in situ one or two weeks previous to transfer to the recipient bed. If one prefers, the tube can be lengthened subsequently, so that the flap will reach a greater distance. Also, one may interrupt the incisions on one side or even on both sides, in order that a tube of almost any length can be raised and transferred later (de River,¹⁰ 1926).

General Indications for the Coverage of Deep Defects.—When one is attempting to select the optimum method for coverage of a scarred ulcerated or deep defect one has to balance the general utility of a skin graft against that of a skin flap. Each has certain advantages. A skin graft can be placed, as a rule,

in one operation in contradistinction to a skin flap which will take at least two, and often more, operative procedures. A skin graft has about normal thickness while a skin flap is often rather thick in appearance. When there is sufficient subcutaneous tissue, a thick skin graft will stand the trauma fairly well even on the bottom of the foot. It gets a nerve supply quicker than a skin flap. The slowness with which a skin flap develops a nerve supply (nearly one year) may be quite a detriment when it is applied over such an area as the heel because of the liability of the development of a trophic ulcer if it is not protected while the nerve supply is appearing. Such lesions as large varicose ulcers often, after wide excision of the scar followed by skin grafting, give a very good result. To use a skin flap for such large lesions is almost out of the question. When sufficient subcutaneous tissue is present and one is aiming solely at surface coverage, a skin graft is preferable to a skin flap.

In general, a skin flap may have the advantages of a fairly high resistance to infection, some thickness for the purpose of filling a defect, lengthening slightly an amputated extremity, and covering with a subcutaneous tissue a thumb or finger reconstructed by means of a bone graft. By means of a skin flap subcutaneous tissue may be supplied to cover exposed tendons, nerves, and bones, to cover certain bases with deficient blood supply such as irradiation ulcers and sloughs, to facilitate the future repair of nerves or tendons, or to allow contemplated operative procedures on tendons, nerves, or bones. The skin is soft and pliable and the color is normal for the area from which it is removed. For the building of organs requiring thickness, for building a part requiring two soft pliable epithelial surfaces and some thickness such as the nose, the cheek, and the lip, and as a direct covering for bone or cartilage, the pedicle skin flap has little competition.

ANALYZATION OF CASES

On analyzation of our series of 97 cases, we find it a little difficult to classify them into groups in many instances because of the individuality of the lesion we were attempting to cover.

Skull Flaps.—The 5 cases of uncoverage of bone of the head fall fairly definitely into type where a sliding or rotation flap of the scalp is used to cover bare bone after removal of the external table of the skull (3 cases) or even the bare dura (1 case) (Fig. 1), or an open sinus (frontal, 1 case). The periosteum of the area from which the skin flap was removed is then covered with a substitute skin graft. In such cases the procedure was a one-stage affair and was in each case successfully accomplished.

Finger, Hand, Arm Flaps.—In 27 cases where a flap or flaps (4 instances) were transferred to either the fingers (Fig. 2), hand (Fig. 3), or arm (Fig. 4), most commonly from the abdomen (26 times), but in 2 instances from back to hand, and in 2 instances lateral chest to arm or elbow region, the operation was a one-stage affair save severance of the pedicle in all but coverage of the elbow, where a tubed pedicled flap of considerable length was deemed necessary. Seven of these flaps were bipedicled or pocket flaps and the remainder were unipedicled with a broad base. In 3 of the latter group the flap did not hold. One of these was a small deep irradiation ulcer of the back of the hand. The other two were to tips of the fingers, one in a small child. It has been found extremely difficult to attach a flap to a small child's finger unless the finger is well pocketed, as often a small child will wiggle his fingers in spite of pain and the fixation that is obtainable. The etiology of these injuries is as follows: 14 were due to some

type of trauma (2 ununited fractures of the leg, 6 to excessive irradiation, 5 were mangle burns, 4 electrical, 1 gunshot, and 1 was due to an ulcer caused by an improperly applied cast). In 9 instances traumatic amputation stumps of the fingers or end of the hand were covered. One case was a quite extensive and deep electrical burn of the shoulder (Fig. 5) which destroyed the deltoid muscle and exposed the shoulder joint. In the correction the shoulder joint was ankylosed and a large flap from the scapular region was turned over the exposed joint and upper humeral region after the dead cortex was removed.

B.



A.



C.



Fig. 1.—This boy sustained an electrical burn which involved particularly the right side of the head and the right dorsal lower ankle and foot. The burn was deep enough that the whole thickness of the skull sequestered. Most of the anterior tendons of the foot sloughed and the bone was uncovered. After about three months the sequestrum of the skull was removed. A large flap from the scalp was thrown from the opposite side of the head to cover the denuded dura. A skin graft was placed on the area from which the scalp flap was removed. This all was done in a one-stage fashion. Later a cartilage transplant from the chest was imbedded beneath the skin flap in such a manner as to overlap bevel fashion the skull edges to give a firm and rounded skull. During this interval after the dead tendons had been removed and the soft tissue had granulated in, somewhat, a skin flap from the opposite calf was placed anteriorly over the lower part of the ankle and dorsal part of the foot. This was also done in a one-stage manner.

A shows the original lesion B shows the final head result. C shows the final foot repair.

Body Flaps.—In the body region were 2 cases of exceptional stubbornness due to intensive irradiation, 1 over the sacral region (Fig. 6), in which a combination of two lateral buttock flaps and a skin graft (4 operations) finally resulted in coverage and relief of pain; the other was an excessive irradiation burn of the groin, lower abdomen, and upper thigh in which three flaps were attempted (1 abdominal flap, 1 thigh flap, and 1 scrotal flap). Each was delayed

before transfer and each sloughed somewhat. Finally septicemia developed, which resulted in a purulent knee joint infection, necessitating amputation. He finally recovered. Operation in the third case was done successfully in one stage by means of a bipedicle upper abdominal flap lowered to the lower abdominal wall after excision of the painful irradiation area. A skin graft was placed in the defect left after removal of the flap.

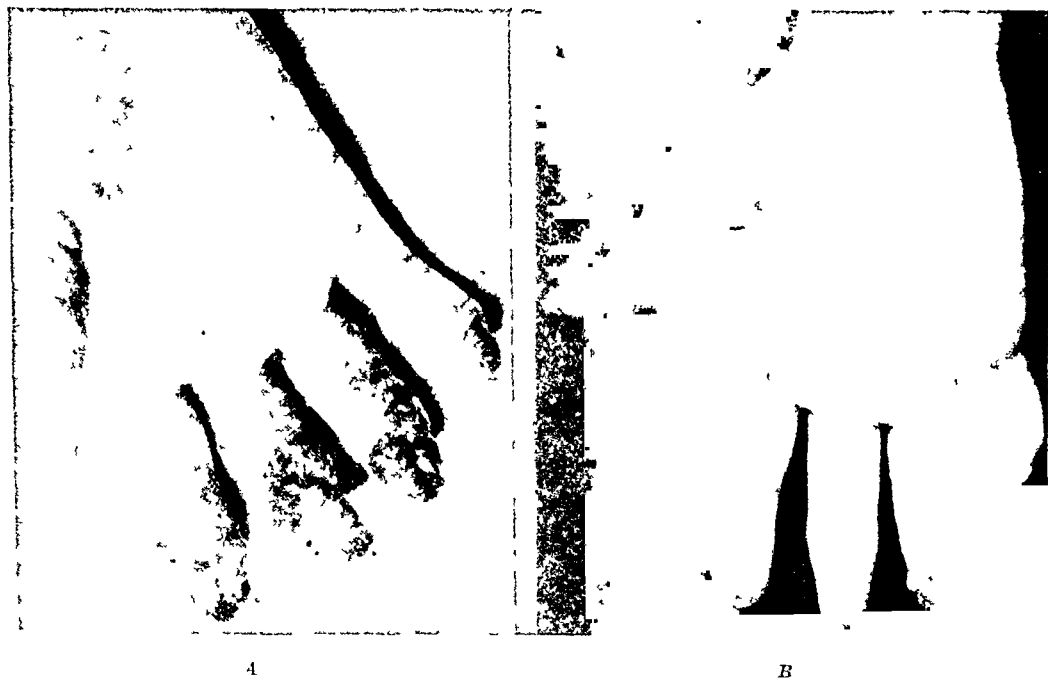


Fig 2—4, A hand which had the distal phalanges destroyed by a mangle. To give padding and to increase the length of the fingers somewhat, flaps from the abdomen were applied to the finger tips. The greater part of the damage was on the ventral surface. B, Final result. (From Padgett, Earl C. *Skin Grafting*, Springfield, Ill., 1942, Charles C Thomas, Publisher, p 80.)



Fig 3—4, A contracture of the hand in which at operation the tendons were laid bare. A skin flap from the abdomen was laid across the palm. B, Result one year later. (From Padgett, Earl C. *Skin Grafting*, Springfield, Ill., 1942, Charles C Thomas, Publisher, p 76.)

Lower Extremity Lesions.—Of the lesions about the thigh, leg, and foot, the etiology of the lesions ran about one-half due to some trauma. Of the other one-half, one-third was due to osteomyelitis, about another one-third was due to a burn, and a final one-third was due to excessive irradiation for some previous lesion. One was due to a frozen foot and one was a trophic ulcer.

Thigh Flaps.—The 13 cases in which flaps were removed from the thigh fall into two classes, one simply a routine affair where the transfer was simple such as delayed transfer from one thigh to the opposite foot (5 cases), sliding laterally over or down over the knee joint in one stage (2 cases), and in one case a delayed or tubed pedicled flap was transferred from each thigh to an opposite leg stump to cover a bilateral below-the-knee amputation (1 case). In a second case a tubed pedicled flap of the thigh was used to cover the end of an amputation stump in a boy with a short below-the-knee amputation. In this case the result has been satisfactory for about ten years. In 2 cases a thigh flap was transferred directly for the purpose of covering a foot defect. In one of these cases the defect was an irradiation ulcer of the whole of the bottom of the foot

A.

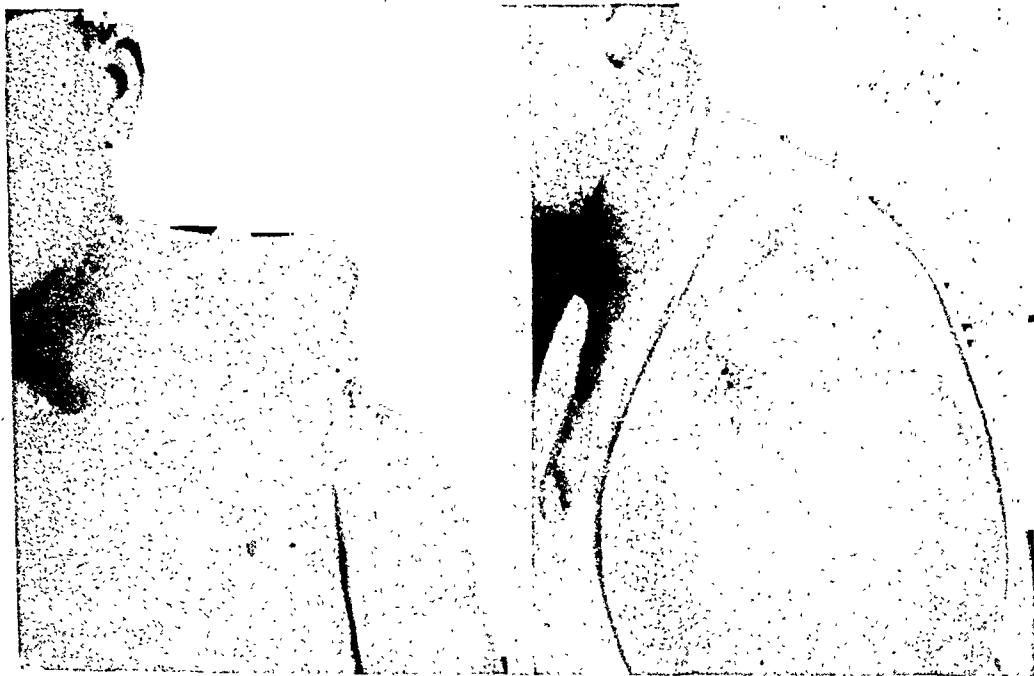


B.

Fig 4—A, This man fell through a greenhouse roof into a manure pile beneath. He was cut across all of the flexor muscles of the forearm and down to the medial nerve. Originally the wound was closed by another surgeon. The patient developed a gas gangrene and the muscles of the arm were laid wide open. The blood supply to the medial nerve was compromised, at the time of the second operation, so that he developed a temporary medial nerve paralysis but eventually the medial nerve regenerated and function became fairly good. To cover the large defect in his arm a large flap from the abdomen was transferred over the defect. A skin graft from the abdomen was applied to the area from which the flap was removed. B, Several weeks after operative procedures

in a woman who originally was supposed to have had a fungus infection. In one case a scarred deformity of the knee was covered by means of a tubed pedicle flap. In a final instance we tried unsuccessfully to cover the exposed bone of the anterior tibial region due to a burn, by means of a reversed tubed pedicle flap taken from the opposite thigh. The distal end of the reversed flap sloughed. We then tried to jump the flap and were also unsuccessful with this

Leg Calf Flaps.—In this series the skin flaps taken from the calf of the leg and transferred to the opposite anterior tibial region (Fig. 7, *A* and *B*), when the ulcerous area was not too large, the malleolar region (Fig. 7 *C*), the anterior



A.

B.

Fig. 5.—*A* and *B*, This patient suffered an electrical burn across the shoulder, which destroyed the deltoid muscle and opened the shoulder joint, exposing the upper end of the humerus. After an interval of time the cortex of the upper end of the humerus was removed. The shoulder joint was ankylosed and a large skin flap was turned from the scapular region to cover the bony defect in the region of the joint of the upper end of the humerus. A skin graft was applied over the scapular area from which the flap was removed.



A.

B.

Fig. 6.—*A*, This woman sustained a very severe x-ray burn of the sacral region from ill-advised deep therapy for menorrhagia. She had severe pain and some ulceration. A flap from the side of the buttocks was turned in over the sacral region. A skin graft was used to cover the area from which the flap was removed and on a place or two on the sacrum we were able to get a skin graft to take. Complete healing and relief of pain was obtained. *B*, Final result.

foot, over the end of a foot stump, the Achilles tendon region, the heel and bottom of the foot, or great toe are the most typical. In 45 cases, 49 flaps of the calf were transferred. In only 3 of these cases was the flap delayed (one six days, one ten days, one thirteen days). Delay was deemed wise because of a leg too fat, scar, or arterial damage. In the remainder of the group transfer was direct. Of this latter group of direct transfer, 2 were lost because of buckling of the base of the flap due to an improperly applied cast (1 complete, 1 partial). In the one partially lost, 5 days later the flap was extended upward, the cast reapplied, and a successful result obtained. In 5 other cases a partial loss of the flap occurred but after the pedicle of the flap was cut long and rotated somewhat, the result was successful coverage. In one case a flap was transferred over the top of each foot and over both Achilles tendon regions in 4 operations not counting the operation for the flap severance (Fig. 8).

As previously mentioned, it is particularly in this group of cases that we believe direct transfer may save much time and many operations for the patient.

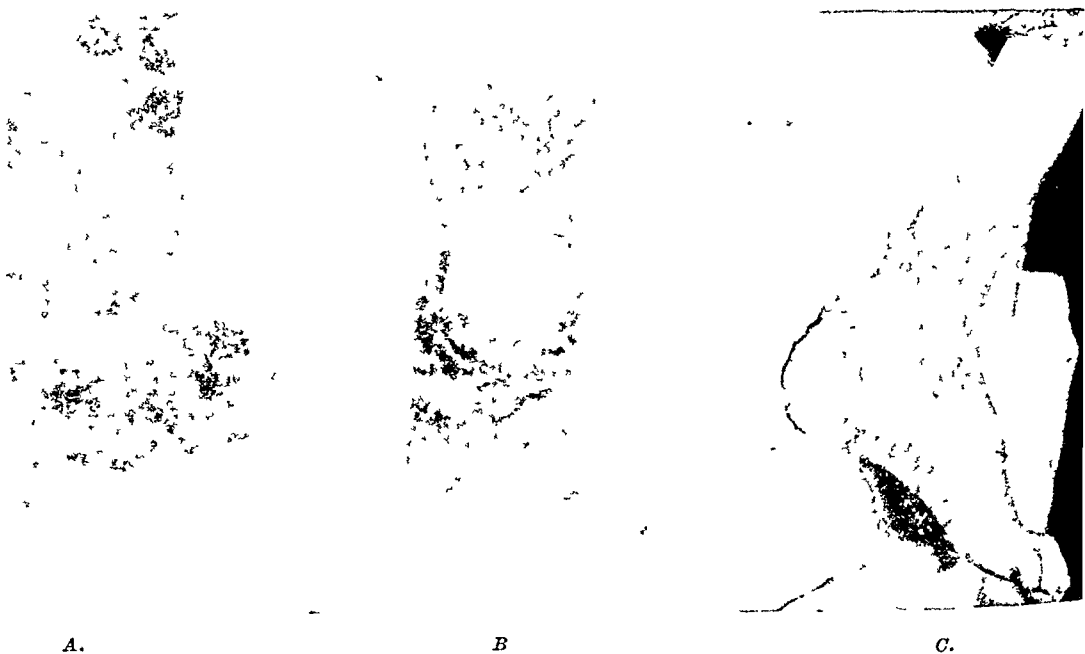


Fig. 7.—A, A patient with a large ulcerating ulcer of the lower anterior tibial and malleolar regions which had not healed for several years. The area was covered with a flap with good result.

B, A patient who had an ulcerating area over the tibial region with nonunion following a fracture. For some reason after a flap was applied over the area the fracture united and the result was good.

C, A patient with an ulcerating area over the external malleolar region. A flap was applied over the area from the opposite calf. In all of these cases the transfer of the flap was carried out in one operation and a skin graft was applied over the area from which the flap was taken on the opposite leg.

One criticism we feel should be made of the calf as a donor site when it is possible to use the anterior, medial, or posterior thigh region in as easy a manner as the calf, is the resultant scarring of the donor area in spite of the application of a skin graft. In a woman this may be objectionable. Often it is preferable to cover an area such as the heel, the external malleoli, or the Achilles tendon by means of a skin flap from the anterior thigh as the flap need not have a long pedicle. To cover the external malleolus, anterior foot, or external tibial region, considerable length to the flap may be required. In such a case the skin flap should be delayed in such a manner as not to jeopardize the blood supply when it is transplanted.

In 4 cases, with nearly the full length of the anterior tibial bone exposed, a bipedicle lateral flap was raised after a relaxing incision was made in the posterior calf region. The flap was then brought forward and sutured to the opposite skin and subcutaneous tissue. A skin graft was then placed in the relaxation defect. In only 1 was the result entirely satisfactory. One became infected; in the other 2 there was partial central loss of the flap which necessitated flap transfer from the opposite calf to give coverage.

CUTTING OF THE FLAP AND FIXATION

To make direct transfer successfully from calf to leg or foot, the calf flap should be cut in the line of the blood supply, with the base upward. When cutting a flap to cover an area on either arm or leg the base should be as wide as possible, the length of the flap must be fairly short, and on the leg the flap should always be taken over the muscular area posteriorly or laterally. A skin graft cut with the dermatome from the abdomen or thigh is applied immediately to the denuded area from which the flap is taken and a proper pressure dressing



Fig. 8.—This child had suffered a destructive lesion of the anterior part of both feet and over the Achilles tendon due to a loop traction allowed to stay on too long after a fracture of both femurs. In this case we transferred four flaps, one to the top of each foot and one over each Achilles tendon. Each flap was transferred in one operation and a skin graft was placed over the area from which the flap was removed. The flaps were removed from the opposite calf each time and a successful result was obtained.
A, Anterior part of the feet before flaps were transferred. B, shows the flaps transferred. C, shows the flap over the Achilles tendon.

is applied over the skin graft. The ulcer base and surrounding scar are removed. Previously, as a rule, all slough, dead tendon, fascia, or bone should have been removed and the base rendered as nearly sterile as possible by means of repeated wet dressings. However, in some cases a completely aseptic wound is not obtainable. The resistance of a skin flap to infection is such, however, that with reasonable precaution in so far as infection is concerned, no difficulty in union will be encountered. Later, especially in the application of the cast, complete asepsis in so far as the flap is concerned is difficult because the flap should be kept under direct vision when it is being stitched in place and when cast or other fixation is being applied if deemed advisable. To hold the arm and hand to the abdomen, adhesive strips are usually adequate. There can be no tension; if the pedicle is rotated it must be a very loose twist. Of course, no pressure can be allowed on

the pedicle after the fixation is applied. Considerable ingenuity as to cutting the flap is required. When transferring a flap from one leg to the other the proper application of the cast is really the sine qua non of the procedure (Fig. 9).

PLANTAR DEFECTS

The common case of this type that one sees is caused by excessive irradiation of a plantar wart or corn. For one case in particular of an irradiation burn in a woman involving the whole of the bottom of the foot, a large lateral flap from the internal thigh was transferred directly, and for some of the fairly large defects of this nature a calf flap was used. These are listed in the preced-

A.



B.

Fig 9—Examples of cast application. A, A flap from the calf of the opposite leg is being turned over the internal malleolus. B, A flap from the opposite leg is being transferred to the bottom of the foot.

ing group (Fig. 10). In 3 instances it was possible to rotate a flap from the bottom of the foot in such a manner that the defect was covered. These were all cases where the defect was relatively small and located under the first metatarsophalangeal joint.

Brown,¹¹ 1944, has stressed the factor of lack of nerve supply after skin flap transplantation to the foot. Theoretically, a patient should not walk on the flap until a nerve supply has developed but by use of crutches or a cane and later by careful padding with foam-latex or neoprene pads in the shoe, plus care to avoid too much trauma or extremes of temperature and attention to cleanliness, atrophic ulceration usually will be prevented from developing. In one of our cases a wart formed between the keratotic normal sole and the flap. This was excised and did not recur.

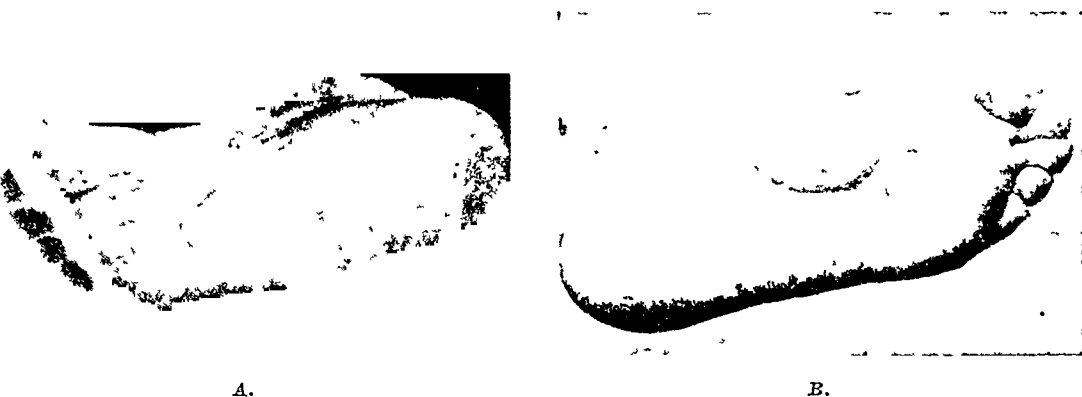


FIG. 10.—Example of hard scar of the inner plantar surface of the foot. There had been some loss of the first metatarsal bone and the lesion was painful and uncomfortable. The scar was excised and a flap from the opposite calf was transferred over the area. The patient obtained considerable relief on walking A, Before, B, result after application of skin flap.

CONCLUSIONS

1. It is emphasized that often a skin flap can be transplanted to the opposite leg, ankle, or foot with safety from the calf or thigh region and the resultant aseptic denuded base from which the flap was removed covered by a skin graft at the first operation, thus saving time and a considerable number of operations.
2. For a traumatically amputated extremity which exposes bone without sufficient soft tissue for coverage, it may be wise to pad the end or the side of the bone with a skin flap if the maintenance of length or lateral padding is desirable. This may be true particularly for the hand and fingers and it is obligatory if one is reconstructing a thumb by use of a bone graft.
3. When tendons in such a location as the hand, fingers, or foot are exposed or if a joint in any location is opened, it is desirable to get immediate coverage by means of a skin flap.
4. Following a severe burn of the hands and fingers, a skin flap may be preferable to a skin graft. In most instances, however, the demand is for the thinner coverage of the skin graft.
5. When a wound has caused loss of the deeper structures including muscle, nerve, and bone, and if reparative operations are contemplated in the future, coverage by a skin flap usually is necessary.
6. If an ulcerated area persists over large tendons such as the Achilles tendon, over bone such as the tibia, the malleoli or top of the foot, the application of a skin flap is desirable.

7. Over the heel and the first metatarsophalangeal joint, if the skin and subcutaneous tissue are absent, a skin flap is necessary because of the trauma to be sustained but great care is necessary for many months until a nerve supply is developed.

8. Over certain areas excessively irradiated with resultant ulceration and pain, especially if the base is of a fibrous nature, the chances of a skin graft taking may be nil or minimal, but after proper excision in most instances a skin flap will become attached and alleviate the discomfort.

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PRACTICAL ASPECTS OF THE TREATMENT OF BURNS

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WE OFFER no apologies, in the presence of the recent voluminous literature on this subject, for presenting certain factors from our experience with burns at the Beekman Hospital which we believe may be of help to others who have to treat these lesions.

The problems presented by burns have been of outstanding interest to one of us (D. G.) for thirty-five years, and, thus, it is of the greatest interest to note the success recent developments have made in preserving lives by plasma, transfusion, fluids, etc., until the vicious cycle of shock and hypoproteinemia has been broken, allowing the victim to survive and permit healing of his wounds.

It is our purpose to present procedures and observations which, though apparently duplicating published methods, we will emphasize wherein they differ and what we feel are advantages.

The Beekman Hospital Ambulance District embraces a large section of downtown Manhattan, affording a cross section of an old Metropolitan City, buildings from the oldest to the newest, with social and economic strata embracing the Bowery, Chinatown, and the financial center of Manhattan. There is a very high atmospheric dust content from steam plants and industrial activity, contaminated from unclean streets, horse trucking, fish markets, shipping, etc. Many of our victims come from lodginghouses and small industrial

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plants not under the sanitary supervision of welfare personnel. Victims from such sources lacking facilities for simple cleanliness present a background for gross contamination of any wound at its reception, to which is commonly added malnutrition and alcoholism with vitamin deficiencies.

In the presence of such possibilities for wound contamination, it is our present belief, from our experience with so little clinical evidence of infection, that burns are relatively clean wounds immediately after the burn has occurred and remain so until contaminated by a source of infection, such as the handling of the patient and the means taken to extinguish the flames of burning garments by rolling on the floor, in rugs, etc. In a case of an explosion where all or a greater part of the clothing is blown from the body, especially over the burned area, or where the exposed parts, as face, neck, hands and arms are burned, it appears to us that a degree of heat which will produce a severe second or third degree burn will destroy surface infection in a measure comparable to the destruction of the tissue which is injured, and infection is largely due to subsequent contamination.

We subscribe most definitely to the immediate covering of burned areas with sterile dressings where normally exposed surfaces are burned. This can be, and is, done from the first-aid ambulance kit. In extensive burns with the clothing destroyed in whole or in part, we believe in our ambulance attendants covering the victim quickly with one or two sterile sheets before covering him with the ambulance blanket. These sterile sheets are carried in a sterile package in the ambulance for such cases and afford a large degree of protection from immediate contamination from the ambulance blanket, which is a potent source of infection even though relatively clean.

When the patient is brought to the emergency room, the surgical staff and charge nurse on the floor are notified. It is the duty of the nurse to direct preparation of the burn bed and have in readiness, at the bedside, the "burn cart" which will be described in more detail later. The surgical staff makes its appraisal, and decisions are made as to the urgent needs of the patient. Morphine, in sufficient dosage to control pain, is given immediately. Shock therapy or prophylaxis should begin at this time in the more serious cases. While the patient is on the stretcher at the bedside, all clothes are completely removed before he is placed in the burn bed. All personnel wear sterile gowns, gloves, caps, and masks. The patient also wears a cap and mask where the forehead and head are not burned. Necessary laboratory procedures are then carried out. Plasma, transfusions, fluids, and electrolytes are given, according to the need as determined by laboratory and clinical findings. In the extensively and critically burned who are on the brink of profound shock, it may be harmful to subject them to the painful and shock-producing procedure of extensive cleansing and débridement. It is advisable in these cases to apply immediately the "petrolatum poultice." In all others, simple cleansing and removal of loose tissue is carried out before the poultice is applied. The cleansing, with the use of detergents when indicated, includes a considerable area beyond the involved portion. An accurate estimate of the extent and probable degree of the burn is recorded.

The procedure to be used following the preliminary preparation depends on the extent and depth of the burn, together with the temperature outside. In cold weather petrolatum poultices with supporting pads may be used freely. In hot weather, where the extent of the burned area calls for so complete a covering of the body with heat insulating dressings, one can add insulation heat stroke to burn toxemia, as exemplified in one of our patients with third

degree burns from mid thighs to ankles, and second degree burns of the body from umbilicus to and including face, neck, and arms, who recovered with a minimum covering of the burned area. The outside temperature was 90 to 94° F. for over two weeks. One must not overlook the fact that the Coconut Grove disaster occurred late in November when swaddling dressings might be desirable for warmth. Under high outside temperatures the dressings are reduced in extent to a minimum with petrolatum poultices to the third degree lesions. The patient is placed on a sterile sheet under a tent arranged for controlling the inside temperature, to which is added a fly net.

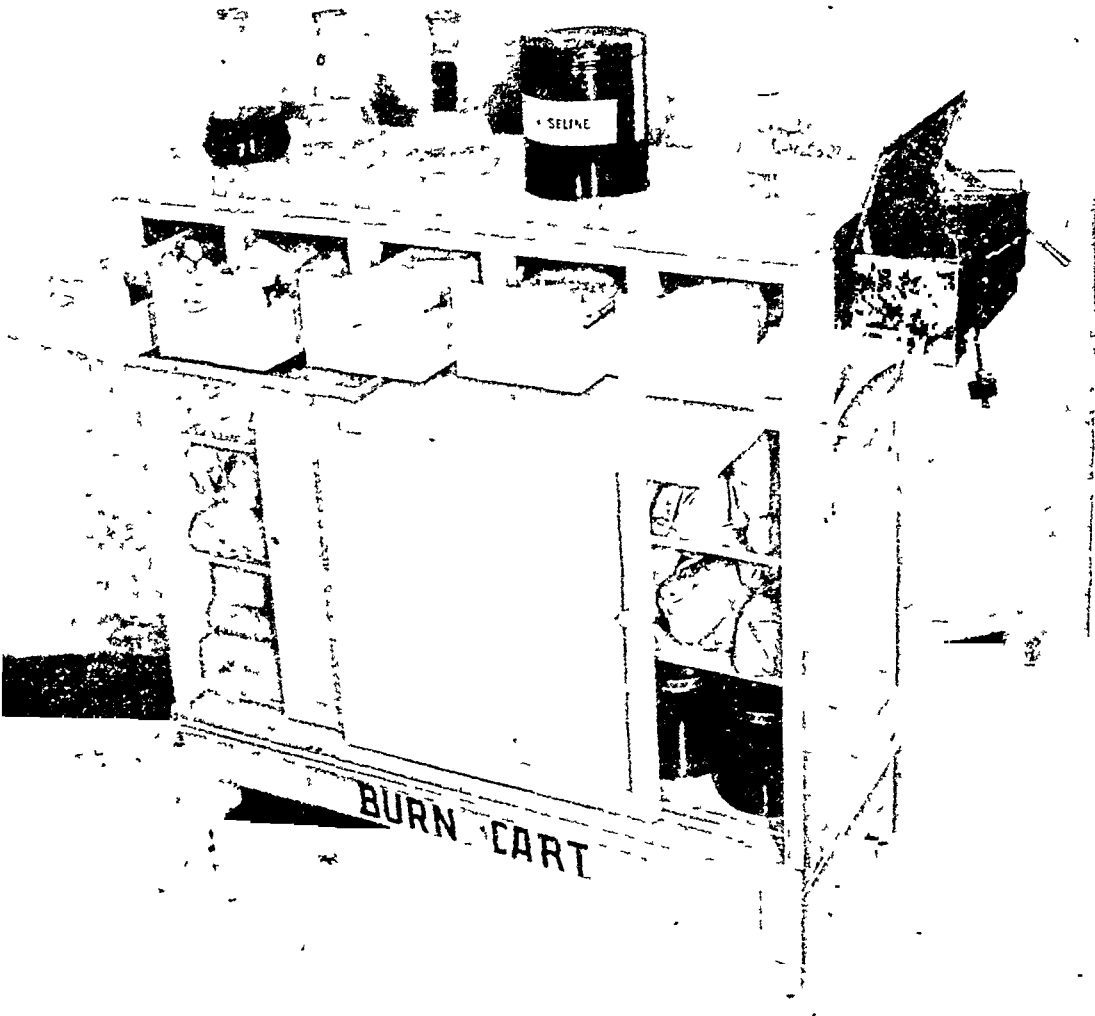


Fig 1—Beekman Hospital burn cart

The "burn cart" was conceived by one of us (L. V. M.) and its contents determined with the same idea behind its use as the well-known "fracture cart." It should be large enough to hold a complete supply of materials for the treatment of several serious burns simultaneously. It should be mounted on wheels swiveled at one end so that it may readily be wheeled where needed. Fig. 1 shows a burn cart we have constructed from an old wooden cabinet. It stands 44½ inches high, 43 inches wide and 17½ inches deep. Fixed to one end is an electric sterilizer for heating our unguents or sterilizing instruments. On the

flat top is arrayed sterile solutions in flasks. Six drawers just under the top contain the numerous smaller items, with an index of contents on the front of each one. Just below these are two sliding work shelves. The lower portion contains the bulky sterile items enclosed by sliding doors. Following is a list of contents:

Sterilizer	Carbon tetrachloride 500 c.c.
Mineral oil, 2 liters	Castor oil, 2 ounces
Detergent solution	Vaseline gauze, 2 tins
Boric acid solution, 250 c.c.	Boric acid gauze, 2 tins
Cotton waste, batting	Sterile leg roll, 1 dozen
Sterile gloves	Gauze pads 4 by 4 inches, 10 packages
Instruments	Gauze pads 2 by 2 inches, 10 packages
Sulfanilamide powder	Green soap
Masks and caps	White soap
Adhesive	Sterile gowns, 3
Safety pins	Combines, 12
Knife blades	Boric acid ointment, 5 pounds
Bandages, 3, 4, 5 inches	Petroleum, 5 pounds
Bandage scissors	Tongue depressors, 4 dozen
Boric acid solution, 500 c.c.	Irrigating cans
Benzine 500 c.c.	Sterile bed linen
Alcohol 70 per cent, 500 c.c.	Sterile basins
Peroxide 500 c.c.	Sterile bandages, 3 to 4 in., 3 dozen

We highly recommend a cart of this type for use in the acute hospital when one or more burn cases are admitted.

The most important and immediate consideration is the prevention and treatment of shock. To this end, morphine in adequate doses, with due consideration for youth or old age, should be given. One-half grain should be the initial dose for adults. This may be repeated in one hour, each specific dose being ordered as necessary. Usually after preliminary sedation, one-quarter grain every three or four hours will suffice. Where involvement of the respiratory tract is suspected, morphine in small doses may be given for other direct indications. The loss of plasma from the burned surface may be huge. This must be replaced from external sources. Where possible and indicated, it is wise to begin the administration of plasma on admission. Conceivably some severely burned individuals may not show a great departure of their chemistry from the normal within one hour from the reception of the injury. However, all such patients receive plasma. A limited balance can be maintained by protein reserves and sacrifices by the uninjured tissues. Acute loss can be built up quickly by administration of plasma. One needle puncture may serve to secure the blood specimen for typing, hematocrit and to begin intravenous therapy. The hematocrit, falling drop, hemoglobin, and red blood count are the tests to judge the requirements of intravenous therapy. Burned patients do not need whole blood in the initial stages. Subsequent anemia will invariably develop at which time transfusions may be administered. Concentration of the blood, with the beginning of shock, tends to help establish a vicious cycle continuing stasis and anoxemia. We prefer to administer 100 c.c. of undiluted plasma for each point above 45 per cent cells on the hematocrit for the treatment and prevention of shock.¹ Marked difficulties still exist in deciding about the need for other fluids. Intravenous normal saline or 5 per cent glucose in distilled water may be given to encourage a urinary output of at least 1,500 c.c. in twenty-four hours. Chloride determination in the urine, if indicative of less than 4 Gm. of sodium chloride excretion in twenty-four hours,

shows the need for intravenous saline. The oral route for fluid intake is ferred and should be encouraged whenever possible. Coffee, weak tea, bonated drinks, and fruit juices are excellent. Often during the early day convalescence, inanition and loss of appetite develop, preventing the nat ingestion of food from aiding in elevating depressed plasma proteins. This further hinders the healing powers of the tissues. For these patients, we have tried to anticipate and have used a Levin tube through the nose into the stomach connected with a drip feeding of pabulum for prophylaxis against the development of low proteins. The formula is the same as is used in jejunostomy findings in postgastric resection cases. We have found this to be dramatic in efficiency.

We emphasize strongly that we feel burns at their inception are clean. Usually they do not require extensive cleansing unless obviously contaminated. Furthermore, a patient precariously on the borderline of impending shock must not be seriously injured by overzealous treatment. For practical purposes we follow a simple plan. The more extensively and deeply burned, the less radical treatment. When the patient is covered with grease or dirt or has brush burns, we clean lightly and irrigate with detergents and saline solution, using gauze sponges. Imbedded particles, especially on the face, should be removed. Detergents have been invaluable in limiting excessive scrubbing. Loose epidermis is removed. Blisters and intact skin are not débrided. The usual burn patient, on arrival at the hospital, receives systemic therapy and immediately has the boric acid poultice applied. Occasionally, the area may be lightly dusted with sulfanilamide powder. Sulfadiazine or one of the other sulfonamide drugs with equal or somewhat greater amounts of the alkaline salts are variably administered by mouth.

Where burned areas are to be exposed they are covered with a layer of petrolatum or borated petrolatum to a thickness of one-third of one inch, using a sterile rubber glove on the hand to apply it. If the surface is too moist from exudation and difficulty is encountered in getting the ointment to adhere, the grease should be put in a sterile container, such as a small sterile pitcher, and heated to a degree where it will not run too freely, and when poured will solidify as soon as it strikes the moist surface. The temperature should not be of such a degree to cause the least discomfort to the patient. As the ointment sets, it should be built up to one-fourth inch thickness and kept there continuously. In using a borated petrolatum, or where a medicament is in suspension in a grease base, one must be careful to avoid precipitation of the drug by too great a degree of heat. If such occurs, cooling in a water bath of ice water while it is stirred with a sterile tongue depressor will restore the suspension. The procedure works excellently on second degree burns of exposed parts of the body such as face, neck, hands, and forearms. In extensive second degree burns of the body including trunk and back, as the ointment melts and runs down onto the sterile sheet, a most perfect petrolatum pressure dressing is afforded the back with compression under which condition epithelization is rapid.

In cases of third degree and deep second degree burns where there is complete epithelial loss between the glandular epithelium, we find that using borated or petrolatum gauze, in the form of what we have called a petrolatum poultice, affords the greatest comfort to the patient, requires infrequent dressings, apparently diminishes lymph loss, and promotes epithelization in a way which exceeds any other technique we have tried. It should be understood that this will not take the place of skin grafting, but from our experience, it helps develop the quickest and healthiest granulations, while the slough is separating.

affording a base for skin grafting on third degree areas while promoting and protecting epithelization on nearby areas of second degree lesions.

A criticism of the thick petrolatum dressing or poultice might be that it macerates tissue by preventing the exudate from being absorbed by the dressings. In answer, we would state that, except in the case of a clean sutured incised wound of the skin, we are unable to recall any healing process which takes place in the body without the presence of tissue fluids either infected or otherwise. Furthermore, we have not seen any maceration with this technique. In our experience maceration occurs only with the improper use of wet dressings.

The petrolatum poultice consists of enough pieces of petrolatum or borated gauze to form a thickness of at least three-sixteenths to one-quarter inch. This is not laid on piece by piece but in the thickness described. Furthermore, it is laid on longitudinally with overlapping edges and extending well beyond the burned area. These are covered with Dakin pads which are bandaged firmly and comfortably but not too snugly. The consistency of the poultice with the external dressings acts as a fair splint. We insist on elevation of the burned limb above the heart, and the upright sitting position where possible, for burns of the face, head, and neck, to diminish lymph loss and swelling. Controlling the swelling in this way, not only diminishes the lymph loss but also, with occasional dependent periods, promotes vascularity of the granulations and epithelization on second degree burns or following skin grafting by avoiding postural ischemia.

High caloric, high protein, high vitamin diet is given when tolerated. We make an effort to see the tray as it leaves the patient rather than when it is received. There should be no delay in noting loss of appetite, since many of these patients are already suffering from subclinical malnutrition. Serious decreases in protein may occur in a short time in these seriously ill patients with poor healing, general debility, and infection.² Intake and output of fluids should be recorded. Most important is a urinary volume of at least 1,500 c.c. with satisfactory specific gravity and about 4 Gm. of sodium chloride excretion in twenty-four hours. During periods of excessive humidity and heat it may not be practical to use the bulky dressings necessary with the present-day pressure dressing technique. Heat loss, both by radiation and evaporation, is impaired and may be the cause of heat stroke. Air conditioning apparatus would solve this problem. Scott-Ivy Pabulum, with forced intragastric feedings, may be used when loss of appetite interferes with satisfactory ingestion.

Dressings are done every three or four days when sloughs are present, a week or ten days otherwise, with reinforcement as necessary. The major loss of plasma continues for about twenty-four to thirty-six hours. Dressings should be snugged especially during this period and for a variable time thereafter. If infection, excessive odor, or lack of comfort results, the dressings may be removed for inspection. For pyocyanus infection, we have used boric acid ointment. Where minute pustules appear in epithelized areas, we have found 1 per cent salicylic acid in boric acid ointment of great help when used locally over the pustule. The dressings slide off as soon as the bandages are cut, neither sticking, nor leaving any bleeding points, nor causing discomfort. Where sloughs are present, there will be an odor. The loose edges and centers of these sloughs are removed as indicated without causing any bleeding. In removing a dressing, a considerable exudate will be obvious. One should not look on this as an expression of infection, unless other signs of infection exist. The wound is irrigated with a detergent solution, weak peroxide and neutral soap, followed by saline solution. Except where sloughs exist, most of the odor will disappear

after cleansing. Infected burns are treated with the usual wet dressings as are other infections followed by early skin grafting when infection has subsided. We have not seen the need for bacteriologic studies to indicate when this may be done. Healthy appearing granulations have been a satisfactory guide.

To get an accurate evaluation of the degree of epithelization and its progress, the wound should be left exposed for a few moments until the surface moisture has dried slightly, then viewed with a magnifying glass using oblique illumination from a flashlight. Where a portion of the granulating area appears dry in contrast to an area obviously moist, one can be assured that the dry area is covered with a delicate epithelial layer, which is not apparent in the moist state. Commonly extending along the advancing edges of the new epithelium, there is a faint pinkish-red line. For many years, one of us (D. G.) has studied this pink line in determining the degree of advancing epithelium on granulating areas on patients. Howes² mentioned this red line observed in studies of epithelization on the rabbit's ear. If it is studied carefully under a magnifying glass, using oblique illumination, it will be seen that the line is formed by a slight concave depression below the surrounding surface. It has appeared to us that this depression is covered only by a single layer of epithelium, which restrains the underlying granulation tissue from becoming redundant at the edges of the advancing epithelium and interfering with its progress, an exceptional example of the inhibitory power of epithelium on granulation growth. Where this line exists, or where there are no redundant granulations, it is absolutely contraindicated to use silver nitrate. The expression one hears of using the latter to "promote granulation" is an absolute fallacy, as its action is entirely destructive. Unless there is an ischemia from underlying scar tissue, granulation tissue requires no stimulation other than that which nature affords. Before redundancy occurs, the marginal granulation can only be restrained by advancing the epithelium by dressings which will not adhere and destroy it on their removal. We find this can be done best by dressings containing an adequate amount of plain or borated petrolatum, to be followed by skin grafts as soon as the sloughs have separated.

Skin grafting is accomplished as early as possible. When the first dressing is done, an appraisal is made of the third degree areas. Second degree burns may be completely healed. Where slough is definitely slow in separating, surgical excision will greatly shorten the period of waiting. If clean areas alternate with infected areas, skin grafting need not be delayed on the clean areas. Pinch grafts insure the greatest degree of success but may only be used on certain portions of the body. If the individual grafts are placed closely together, the cobblestone effect will be diminished. The primary dressing for skin grafts is the paraffin mesh gauze with adhesive and covered with dry gauze. When the graft has adhered we use the petrolatum poultice to enable the epithelium to spread.

Before the sulfonamide drugs appeared, we used borated petrolatum in large amounts and still do for its ability to prevent pyocyanus infection and its capacity of adhering to moist surfaces, when it is brought to the proper temperature. Though aware of its possible toxic action, we have not observed any.

We use one of the sulfonamide drugs locally and orally to combat infection, whenever we feel they are indicated.

Where applicable on limbs we have made use of the whirlpool bath to aid in separating sloughs and to improve vascularity under healed areas, which have been skin grafted as soon as they will tolerate moisture.

Contractures are combated by placing the limbs in extension and splinting them to prevent muscle spasm inducing contractures. If the dressings are voluminous enough they will sometimes be sufficient, provided they are made comfortable, which the thick grease dressing does. Where feasible, elevation is arranged by suspension from an overhead fracture frame, which permits movements, active and resistive, at the earliest possible time. We have used these "resisted" exercises in flotation to overcome muscle spasm and increase the range of motion of major joints. With the aid of pulleys at each end of the bed and light, graduated traction weights, the extensors and flexors are exercised alternately and independently. The value of this type of muscle exercise has been little appreciated. We have used them successfully in many types of injuries.

Such exercise tends to diminish all the factors which predispose to spasm, atrophy of tissue, and contractures, thus avoiding some of the sequelae of burns. The cooperation of the patient in doing these exercises cannot be obtained unless these movements are without pain or discomfort.

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MORTALITY FACTORS IN ACUTE APPENDICITIS

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ALL reports of patients with acute appendicitis operated upon at the Peter Bent Brigham Hospital in the years 1913 (when the hospital first opened its doors) through 1940 were reviewed in a previous publication.² It was surprising and disappointing that an analysis of mortality rates by five-year periods failed to show any appreciable improvement with the passing of time (Table I). Even during the last period, when much might have been expected of chemotherapy in this field of surgery, patients were lost despite heavy treatment with sulfonamides (Table II). Furthermore, the mortality figures do not differ greatly from those reported from comparable institutions (Table III).^{1,3,4,5,6} The failure to improve with the passage of time stimulated a detailed study of all the fatal cases during this twenty-eight year period in an effort to shed further light upon factors in management which influence the mortality.

The series is a selective one to this extent: children under the age of 12 are not included; neoplasm or tuberculosis of appendix or cecum is excluded even if associated with acute infection.

There are 106 recorded deaths from acute appendicitis from 1913 through 1940 (Table IV). There were autopsies in 56 of the total deaths, or 53 per cent. Five patients had no operation and have been eliminated from this study; these cases actually prove only that a patient may die without operation, and con-

TABLE I. ANALYSIS OF DEATHS FROM APPENDICITIS—MORTALITY RATE BY FIVE-YEAR PERIODS*

YEARS	TOTAL CASES	DEATHS	MORTALITY (%)
1913-1920	475	26	5.5
1921-1925	422	17	4.0
1926-1930	405	15	3.7
1931-1935	375	17	4.5
1936-1940	518	25	4.8
1913-1940	2,195	100	4.6

*Operative deaths only.

TABLE II. ANALYSIS OF DEATHS FROM APPENDICITIS—PATIENTS RECEIVING SULFANILAMIDE THERAPY

YEAR	AGE	SEX	TYPE OF APPENDIX	LOCATION	CATHARTIC	DURATION OF SYMPTOMS (DAYS)	PERITONEAL CULTURE	PERITONEAL SULFANILAMIDE	ADEQUATE DOSAGE	P.O. SURVIVAL (DAYS)
1938	25	M	Perforated	Iliac fossa*	No	5	B. coli	No	Yes	12
1940	69	M	Abscess (I & D)	Iliac fossa†	Yes	5	B. coli nonhem. strep. B. coli	No	Yes	7
1940	67	M	Perforated	Retro-ileal‡	No	3	B. coli	Yes	Yes	4

*Patient had a very toxic course

†Death from pylephlebitis

‡Death from progressive peritonitis

TABLE III. ANALYSIS OF DEATHS FROM ACUTE APPENDICITIS—MORTALITY RATES IN LEADING CLINICAL

AUTHOR	MICRO-SCOPIC CONTROL	ACUTE UNRUPTURED APPENDICITIS		ACUTE PERFORATED APPENDICITIS		APPENDICAL ABSCESS		TOTAL	
		CASES	MOR-TALITY (%)	CASES	MOR-TALITY (%)	CASES	MOR-TALITY (%)	CASES	MOR-TALITY (%)
Sch and Spivack, New York, Beth Israel Hospital, 1931-36	Yes	492	0.4	52	13.5	91	6.6	635	
Davis and McLaughlin,† Omaha, U. of Neb. Hospital, 1932-1938	?	784	0.5	124	13.7	50	8.0	958	
Reid and Montanus, Cincinnati, Cinn. Gen. Hosp., 1934-1938	?	583	1.0	209	17.2	129	10.1	921	
Haggard and Kirtley, Nashville, Haggard Clinic, 1915-1938	?	2,007	0.6	189	24.8	417	5.8	2,613	
Stafford and Sprong, Baltimore, Johns Hopkins Hosp., 1931-1939	?	838	0.0	196	14.2	283	7.1	1,317	
Cutler and Hoerr, Boston, Peter Bent Brigham Hosp., 1913-1940	Yes	1,604	1.2	339	17.1	247	7.3	2,192†	

*Figures adapted and made comparable to those of Peter Bent Brigham Hospital.

†This series excludes entirely five moribund patients.

‡Total figure includes two anesthesia deaths.

TABLE IV. ANALYSIS OF DEATHS FROM APPENDICITIS—FATAL CASES

No operation	5
Operation at another hospital	1
Death in the operating room	2
Death from extra-abdominal causes	18
Death from progressing appendicitis	80
Total	106

tribute nothing to a study of operative management. In one instance operation was performed in another hospital and for this no responsibility is assumed. Two patients died in the operating room, presumably from anesthesia. Eighteen died from causes which are arbitrarily called *extra-abdominal*; in these patients the appendicitis was controlled as far as could be judged from the clinical course and from the autopsy when one was done (Table V). There remain 80 patients in whom death occurred as a result of unchecked appendicitis or its direct complications, that is, from *abdominal* causes.

TABLE V. ANALYSIS OF DEATHS FROM APPENDICITIS—EXTRA-ABDOMINAL CAUSES OF DEATH

Pulmonary embolism	9 (youngest age 45)
Pneumonia	2
Coronary occlusion	1
Diabetic coma	1
Hemorrhagic purpura	1
Diabetes and nephritis	1
Uncertain	3
Total	18 (6 younger than 50)

Cases have been placed in one of three groups: acute perforated appendicitis if a gross perforation was described either by the surgeon or by the pathologist; appendical abscess if the surgeon found localized pus; acute unruptured appendicitis if there was no localized pus or gross perforation. In all cases when the appendix was removed there was microscopic verification of the operative diagnosis.

The criteria for grouping described here are not without disadvantage, but they are simple and applied with relative ease. Many cases of severe appendicitis with gangrene, and even a general peritonitis with a positive peritoneal culture, have been placed in the unruptured group because there was no gross perforation; an appendix broken in removal has likewise been regarded as unruptured. This has been necessary to avoid inconsistencies in the estimate of the extent of the peritoneal involvement by the many different surgeons. Although the peritoneal culture offers an accurate means of determining the presence of infection beyond the appendix, it could not be used as a criterion in this series because of the infrequency with which cultures were taken fifteen or twenty years ago.

Attention has been focused upon the 80 patients who died of progressive appendicitis. It is reasoned that the *extra-abdominal* causes of death are common to all types of disease, medical as well as surgical, and cannot directly be related to factors in the management of acute appendicitis. In death due to *abdominal* causes, on the other hand, it must be assumed that in each instance, for whatever reason (not the least being delay in hospitalization), the appendicitis was inadequately treated.

The study has been developed in two ways: first, a consideration of the clinical aspects of the fatal cases; second, a modification of previously derived mortality statistics by excluding those cases in which death was not directly attributable to the abdominal disease, as in pulmonary embolism or coronary thrombosis.

ANALYSIS OF DEATHS DIRECTLY DUE TO PROGRESSIVE APPENDICITIS

Chief Clinical Features in Abdominal Deaths.—It is to be expected that the patients in the vast majority of these fatal cases already have advanced appendicitis at the time of operation. This is borne out by the fact that at operation 53 had perforations, 14 had appendical abscess, and only 13 of the

80 were unruptured. In Table VI is indicated in the order of frequency the principal clinical feature of the fatal cases cross-analyzed with respect to the findings at the time of operation. A peritonitis which continued to develop despite the operative procedure accounted for 22 patients; 17 died within fourteen days of the initial symptom. Next in frequency was the existence of two or more persistent and undrained abdominal abscesses; more than one-half of the patients (6 of 11) lived more than fourteen days after the initial symptom. Nine suffered from a serious extra-abdominal disease as well as progressive peritonitis: 4 had diabetes, 2 had heart disease, and 1 each had chronic nephritis, pulmonary tuberculosis, and massive pulmonary atelectasis.

TABLE VI. ANALYSIS OF DEATHS FROM APPENDICITIS—CHIEF CLINICAL FEATURE IN "ABDOMINAL" DEATHS, ACUTE APPENDICITIS

	ALL CASES	TYPE OF APPENDICITIS		
		UNRUPTURED	PERFORATED	ABSCESS
Progressive general peritonitis	22	4	17	1
Multiple abdominal abscesses	11	2	7	2
General peritonitis and serious extra-abdominal disease	9	2*	3	4
Fulminating or very toxic course	8	2	6	-
Arrived in hospital "moribund," in "shock," or as "very poor risk"	7	-	7	-
Severe ileus	5	-	3	2
Mechanical intestinal obstruction	5	-	5	-
Single abdominal abscess	4	-	2	2
Pylephlebitis	4†	2	1	1
Metastatic abscesses or pyemia	3	-	1	2*
Anesthetic death at second operation	2	1	1	-
Total	80	13	53	14

*Includes one case with incidental pylephlebitis.

†Two additional cases of pylephlebitis placed in other groups.

Patients whose course was fulminating, or who arrived at the hospital in a critical condition, are similar in that in these individuals the virulence of the bacterial infection appears to be the decisive factor. It is noteworthy that of the 15 patients included in these two groups, 13 had a perforated appendicitis, and 13 died within seven days of the onset of the disease.

The remaining fatal cases fall into clinical groupings which claim only a few patients in each: severe ileus, mechanical intestinal obstruction, single abdominal abscess, pylephlebitis, pyemia, and anesthetic death at a second operation.

If one looks at the data contained in Table VI with the coldly suspicious stare which surgeons employ when scrutinizing the mortality figures of others, an impression is obtained that certain of these patients might have been saved. Perhaps the 10 patients who died from severe ileus or mechanical intestinal obstruction would have lived had they had prompt and efficient gastrointestinal siphonage, an operative freeing of adhesions, or an enterostomy at the proper time. (Three of them actually did have unsuccessful secondary operative procedures.) The abscess should have been suspected and properly drained in the 4 patients who had a single large residual abscess and possibly some of the 11 patients with two or more abscesses could have been saved with judicious use of the scalpel. (Only 5 of the 15 in the combined groups with residual abscesses had secondary incision and drainage.) The 2 patients who died of anesthesia at a second operation might represent a lack of care either in the choice of anesthesia or the preoperative preparation. One cannot generalize without further data concerning the remaining 53 patients who died of progressive peritonitis, who had violent bacterial infection, or who developed pylephlebitis or pyemia.

Promptness of Operative Treatment.—It has long been recognized that delay in operation when acute appendicitis is in its early stages is perhaps the greatest single factor contributing to mortality; the generally accepted reason is that delay permits the complications of free perforation or abscess formation to take place. Only 13 of the 80 patients were operated upon within the first 48 hours of the disease. In Table VII the operative findings are described as related to the duration of the disease. This table merely notes delay and does not assign the blame to patient, physician, or hospital. Of interest is the fact that unruptured appendicitis was found as late as four days after the initial symptom in two fatal cases.

TABLE VII. ANALYSIS OF DEATHS FROM APPENDICITIS—OPERATIVE FINDINGS RELATED TO DURATION OF SYMPTOMS

DURATION OF SYMPTOMS TO OPERATION	TYPE OF APPENDICITIS		
	UNRUPTURED	PERFORATED	ABSCESS
48 hours or less	4	8	1
49 to 72 hours	4	11	—
73 to 96 hours	3	15	2
More than 4 days	2	19	11
Total	13	53	14

In Table VIII is shown the extent to which the hospital must assume responsibility for delay in operation. It is indeed striking that 58 patients, nearly 3 out of 4, were operated upon within six hours of reaching the hospital; this clearly points the lesson that speed in getting the patient to the operating room will of itself not save these lives. The fatal delay in these patients must be assumed to have taken place before they reached the hospital.

TABLE VIII. ANALYSIS OF DEATHS FROM APPENDICITIS—HOSPITAL DELAY IN OPERATION

No delay (operation within 6 hours)	58
Delay more than 6 hours	22
Refusal of patient	2
Diagnosis uncertain	16 (6 longer than 24 hours)
Diagnosis certain, therapeutic	4 (all longer than 24 hours)

Occasionally patients will die even if operated upon promptly after the onset of symptoms, but they do not reach impressive numbers. Only 6 patients in the present series died after an operation performed within thirty hours of the first symptom, less than 8 per cent of the fatal cases; details are given in Table IX. It is significant that 5 had received cathartics, that perforation had already taken place within the thirty hours in 5, and that 3 had a fulminating infection. All of the patients were 45 years of age, or older. All of the cases occurred before chemotherapy was available. Perhaps the sulfonamides would have saved some of them.

TABLE IX. ANALYSIS OF DEATHS FROM APPENDICITIS—OPERATION WITHIN THIRTY HOURS OF FIRST SYMPTOM

YEAR	AGE	SEX	TYPE OF APPENDICITIS	LOCATION	CATHARTIC	TOTAL SURVIVAL (DAYS)	COMMENT
1913	47	M	Perforated	Iliac fossa	Yes	11	Multiple abscesses
1925	45	M	Unruptured	Pelvis	Yes	4	Fulminating course
1929	67	F	Perforated	Iliac fossa	Yes	13	Marked ileus
1932	47	M	Perforated	Retrocecal	Yes	2	Fulminating course and massive pulmonary atelectasis
1936	49	M	Perforated	Pelvis	No	10	280 lb. severe diabetic; multiple abscesses
1938	57	M	Perforated	Retro-ileal	Yes	6	Fulminating course

TABLE X. ANALYSIS OF DEATHS FROM APPENDICITIS—UNCERTAIN OR INCORRECT PREOPERATIVE DIAGNOSIS*

PRESUMPTIVE DIAGNOSIS	NUMBER CASES	OPERATIVE DELAY		
		NONE	7-24 HR.	25 HR. +
Intestinal obstruction	6	2	4†	-
General peritonitis, unknown cause	3	1	1	1
Renal disease (?)	3	1	-	2
Biliary tract disease (?)	3	1	2	-
Gynecologic disease (?)	2	-	1	1
Perforated peptic ulcer	1	1	-	-
"Medical disease"				
Typhoid	1	-	-	1
Pneumonia	1	-	1	-
"Appendicitis unlikely"	3	-	2	1
Total	23	6	11	6

*23 cases: 3 unruptured, 14 perforated, 6 abscess.

†One patient refused operation temporarily.

As far as hospital delay is concerned, the most challenging problem is presented by the patient whose operation is postponed because of uncertain diagnosis. In Table X are particularized the fatal cases which presented initial diagnostic difficulties (although in 6 instances it did not result in appreciable delay). There is little to add since the protean manifestations of acute appendicitis are widely appreciated. One must weigh in each individual the disadvantage of delay in a possible appendicitis against the advantage of not operating upon a patient critically ill with coronary thrombosis, pneumonia, or nephritis. Cases in which the patients have been spared operation by judicious observation are not tabulated in this paper, nor is it easy to find these records in hospital archives. It is worth noting, however, that of the 23 patients who were diagnostic problems, in only 8 were conditions suspected in which abdominal exploration would be contraindicated, that is, renal disease, "appendicitis unlikely," and "medical" disease. Earlier operation as a step in diagnosis should be considered when the differential lies between appendicitis and such conditions as intestinal obstruction or acute salpingitis, utilizing, if necessary, two incisions (exploring the appendix first) in order to avoid tragic delay.

Operative Procedure.—In Table XI is shown the operative procedure which was carried out in the 80 cases. The conclusion one reaches is that some patients will die irrespective of the procedure carried out. Except for the localized abscesses there will be few occasions when appendectomy cannot be carried out. On these grounds one may question the circumstances in which a simple incision and drainage was the only procedure done in 6 patients with free perforation. Actually, however, in 3 cases appendectomy was not carried out because the appendix could not be readily found and was presumably so necrotic that it was no longer recognizable; in 1 case operation was carried out through an upper abdominal incision under the mistaken diagnosis of acute cholecystitis, and the correct diagnosis was found only at post-mortem; in the other two instances surgeons of experience operating upon desperately ill pa-

TABLE XI. ANALYSIS OF DEATHS FROM APPENDICITIS—OPERATIVE PROCEDURE

TYPE OF APPENDICITIS	APPENDECTOMY			INCISION AND DRAINAGE	
	NO DRAINS	DRAINS	ENTEROSTOMY	SIMPLE	ENTEROSTOMY
Unruptured	2	11	-	-	-
Perforated	1	41	3	6	2
Abscess	-	7	-	7	-
Total	3	59	3	13	2

tients contented themselves with the simplest operative procedure and perhaps avoided a fatality on the operating table thereby.

A cross-analysis of the location of the appendix with reference to the type of incision is given in Table XII. Four patients with pelvic appendicitis were operated upon through a McBurney incision; 15 patients with retrocecal appendicitis had right rectus incisions. Although a reversal of these incisions might have been more suitable, only one-quarter of the patients is involved, and it is obviously not a matter of first magnitude. Furthermore, the disagreement existing between surgeons of wide experience is evidence that the choice of incisions is not of fundamental importance. In this clinic we happen to incline to the McBurney incision as the one of preference in all instances except pelvic appendicitis or in diagnostic problems in women. To revert to first principles, however, one may say that the proper incision in any given case is the one which will give the surgeon the best access to the appendix with the least disturbance to the remainder of the peritoneal cavity. As in one case in the present series, such an incision may occasionally be in the left upper quadrant (where the undiagnosed appendicitis lay).

TABLE XII. ANALYSIS OF DEATHS FROM APPENDICITIS—LOCATION OF APPENDIX RELATED TO OPERATIVE INCISION

LOCATION	NUMBER CASES	INCISION			
		RIGHT RECTUS	MC BURNEY	MIDLINE	OTHER
Iliac fossa	35	22	7	6	—
Retrocecal	22	15	6	—	1*
Pelvis	18	12	4	2	—
Retro-ileal	2	1	1	—	—
Subhepatic	1	—	—	1	—
Left upper quadrant	1	—	—	—	1†
Not specified	1	1	—	—	—
Total	80	51	18	9	2

*Right upper rectus incision for supposed acute cholecystitis.

†Left upper rectus incision.

It would be foolish indeed to underestimate the importance of what the surgeon did and how he did it in sizing up the outcome in a particular case of acute appendicitis. Only rarely is it possible to surmise from the operative notes themselves that an improper operation has been performed. In one fatal case the surgeon took nearly two hours to carry out a painstakingly thorough exploration of the entire abdomen in a critically ill patient with a perforated appendicitis before finding and removing the offending organ. This death must surely be blamed upon the surgeon. In the overwhelming majority of instances, however, the operative note does not indicate the presence or absence of those intangible but all-important factors of gentleness, skill, and good judgment. In this series with an average of only four or five deaths a year it is impossible to incriminate individual surgeons on statistical grounds, for one surgeon might be unfortunate enough to operate upon a succession of patients whom the most skillful surgery could not save. It is necessary, therefore, to adopt statistical methods in order to pool the experience of the entire hospital staff. A further analysis of the role of the type of incision and the use of drains will be dealt with statistically in the second part of this paper.

Fatal Acute Unruptured Appendicitis.—Thirteen patients who died of progressive appendicitis had neither a perforation nor a localized abscess at the time of operation. It was pointed out earlier in this paper, however, that the system employed in grouping cases does not preclude a serious infection al-

ready existing beyond the appendix although it has not grossly perforated. In Table XIII this point is demonstrated by showing that the peritoneal culture was positive in the six instances when it was taken. Nine patients were known to receive cathartics. That drainage of the peritoneal cavity will not save these patients is proved by the fact that drainage was carried out in 11. Perhaps it is significant that there has been no fatal case in this group since 1933; chemotherapy might well have turned the scales in some.

TABLE XIII. ANALYSIS OF DEATHS FROM APPENDICITIS—ACUTE UNRUPTURED APPENDICITIS*

Entered hospital 48 hours or more after onset	9
Received cathartic	9
Operative delay from incorrect diagnosis	1
Drained at operation	11
Age under 15	5
Age over 50	4
Peritoneal culture	
Positive	6
Negative	0
Not taken	7
"Unavoidable" deaths	
Pylephlebitis	2
Congestive heart failure	1
Pulmonary tuberculosis	1
Anesthetic death, 2nd operation	1

*13 cases (none since 1933).

Chemotherapeutic Failures.—Although the sulfonamide drugs have been unanimously received as welcome and potent new weapons in the treatment of acute appendicitis, some of the earlier reports of their use have been somewhat overoptimistic. In Table II (previously referred to) are listed details concerning 3 patients who died although they had received what is generally regarded as adequate dosage of one of the sulfonamides. One of the three was given intraperitoneal drug as well. Several additional fatal cases where chemotherapy was employed late or in insufficient dosage have not been included. These cases are cited as a reminder that the "wonder drugs" are not invariably effective. The existence of a promising new therapeutic weapon must not blind us to the importance of the many other factors involved in the proper care of a patient with acute appendicitis: a well-timed and properly executed operation; effective decompression of the gastrointestinal tract; maintenance of nutrition with blood and plasma transfusions. When these other features can be forgotten, acute appendicitis will properly cease to be a surgical problem and can be treated by anyone who can follow a dosage schedule.

Extra-abdominal Disease, Preoperative and Postoperative.—Fourteen of the 80 patients had a serious constitutional disease antedating the acute appendicitis; 6 had diabetes, 6 had heart disease (3 developing congestive failure), 1 had chronic nephritis, and 1 had pulmonary tuberculosis. Thirty patients developed a postoperative pulmonary complication; the various types are listed in Table XIV. The nine instances in which it was felt that the extra-abdominal disease played an important contributory role in the fatal issue have already been referred to. In the remainder, although additional disease is always unwelcome, either the severity of the appendicitis was such as to overshadow anything else, or the disease was sufficiently controlled (as in mild diabetes) to be considered relatively unimportant.

Miscellaneous Data.—Table XV lists various facts which are of general interest. This emphasizes the preponderance of men, the large proportion of patients entering the hospital forty-eight hours or more after the onset of symp-

TABLE XIV. ANALYSIS OF DEATHS FROM APPENDICITIS—POSTOPERATIVE PULMONARY COMPLICATIONS*

Atelectasis	7
Bronchopneumonia	6
Pleurisy	3
Lobar pneumonia	2
Massive atelectasis	1
Empyema	1
Metastatic abscesses	1
Terminal bronchopneumonia	0
Total	30

*30 of 80 cases: 38 per cent.

TABLE XV. ANALYSIS OF DEATHS FROM APPENDICITIS—MISCELLANEOUS DATA, EIGHTY ABDOMINAL DEATHS

Entered hospital 48 hours or more after onset	67
Received a cathartic	49
Operation delayed more than 6 hours for diagnosis	16
Admission pulse	
100 or more	62
120 or more	22
Duration of operation	
One hour or less	61
More than 1½ hours	3
Peritoneal culture	
Positive	45
Negative	5
Not taken	30
Sex	
Males	54
Females	26
Age	
Over 50 years	24
Over 70 years	8

toms, the frequency with which cathartics had been taken, and the high proportion of positive peritoneal cultures.

MORTALITY STATISTICS BASED UPON ABDOMINAL CAUSES OF DEATH

We are utilizing the concept of extra-abdominal and abdominal causes of death in deriving a new series of mortality statistics which excludes those patients dying from extra-abdominal causes. The 18 cases listed in Table V have been "thrown out" from the statistics which follow just as if the patients had never entered the hospital. It has seemed fair to assume that the operative management of these 18 cases could not be blamed for the fatal result, since in each instance, as far as could be determined, the appendicitis was fully checked, improving, or (in 1 or 2 cases) healed. On the other hand, it is highly unreasonable to regard these patients as successfully treated. Hence their rigid exclusion. The 5 patients who died without operation, and the patient who died following an operation in another hospital and the two anesthetic deaths are likewise excluded.

The following statistics, then, are based upon every case of acute appendicitis in which the patient was treated by operation in the Peter Bent Brigham Hospital in the years 1913 through 1940, with the exceptions just given. Every case in the 2,175 under consideration had pathologic verification of the diagnosis except in those rare instances when the appendix was not removed; in such cases the operative diagnosis was beyond reasonable doubt. The criteria for classifying cases as unruptured, perforated, and abscess have already been explained and have been rigidly followed, in the successfully treated patients as well as the fatal cases. The importance of pathologic control and strict

criteria for grouping cannot be overemphasized if statistics are to be of value. The possible consequences of loosely applied criteria are suggested in this hypothetical series.*

TABLE XVI. ANALYSIS OF DEATHS FROM APPENDICITIS—MORTALITY RATE BY FIVE-YEAR PERIODS BASED UPON ABDOMINAL DEATHS

YEARS	TOTAL CASES	DEATHS	MORTALITY (%)
1913-1920	473	24	5.1
1921-1925	417	12	2.9
1926-1930	403	13	3.2
1931-1935	373	15	4.0
1936-1940	509	16	3.1
1913-1940	2,175	80	3.7

General Mortality Rates.—In Table XVI are given the mortality figures in abdominal causes of death by five-year periods (compare with Table I). It can be seen that even with this new concept there has been no significant improvement in twenty years. In Table XVII these figures are further broken down into the three great groups of appendicitis; once again no improvement of any

TABLE XVII. ANALYSIS OF DEATHS FROM APPENDICITIS—MORTALITY RATE BY FIVE-YEAR PERIODS BASED UPON ABDOMINAL DEATHS

YEARS	ACUTE UNRUPTURED APPENDICITIS		ACUTE PERFORATED APPENDICITIS		APPENDICAL ABSCESS	
	CASES	MORTALITY (%)	CASES	MORTALITY (%)	CASES	MORTALITY (%)
1913-1920	294	1.4	97	17.5	82	3.7
1921-1925	315	0.3	52	17.3	50	4.0
1926-1930	305	1.3	56	12.5	42	4.8
1931-1935	283	1.4	50	14.0	40	10.0
1936-1940	402	0.3	78	15.4	29	10.4
1913-1940	1,599	0.9	333	15.6	243	5.8

significance can be shown.† In effect, these tables say that despite improved technique in the operating room, in spite of better understanding of gastrointestinal physiology and the role of gastrointestinal siphonage, in spite of closer attention to fluid balance and nutrition, we are not saving any more patients today than we did twenty years ago.

Relation of Type of Incision and Mortality.—In Table XVIII the incision employed is cross-analyzed with respect to the type of appendicitis, and the

*Let us assume a hypothetical series:

Acute unruptured appendicitis			Acute perforated appendicitis		
Cases	Deaths	Mortality	Cases	Deaths	Mortality
1,000	10	1%	200	30	15%

Now let us suppose that we do not use microscopic verification for our diagnosis of acute appendicitis, and add 100 cases of "clinical" acute appendicitis where the operator has, for one reason or another, called a normal appendix "acute." (This will happen occasionally to the best and most conscientious surgeons, and frequently to poor ones.) In none of these 100 new "acute" cases is the patient likely to have died. Now let us transfer over to the perforated group 100 cases from the acute unruptured group; let us say these were severe cases with a gangrenous appendix, many with a cloudy peritoneal fluid and perhaps evidence of a generalized peritonitis (perhaps even a positive culture), fitting a loose grouping of "perforated" appendicitis; let us say that in three of this transferred group the patient died. The following figures result:

Acute unruptured appendicitis			Acute perforated appendicitis		
Cases	Deaths	Mortality	Cases	Deaths	Mortality
1,000	7	0.7%	300	33	11%

The mortality figures in both groups have undergone a definite improvement. It is probably a safe guess that at least some of the very favorable figures appearing in the literature are a result of unconscious "padding" such as this. Deaths cannot be wished away, but the groups in which they fall can be so swelled that mortality rates are misleading.

†The following formula has been used for determining a significant difference between mortality rates in two series:

Series 1		Series 2	
No. of cases	Mortality	No. of cases	Mortality
X	A%	Y	B%

Suppose A greater than B, the difference is then A-B. This difference is significant if

$$\sqrt{\frac{A \times (100 - A)}{X} \text{ plus } \frac{B \times (100 - B)}{Y}} \text{ is greater than 2.}$$

TABLE XVIII. ANALYSIS OF DEATHS FROM APPENDICITIS—COMPARISON OF INCISION AND MORTALITY (BASED UPON ABDOMINAL DEATHS)

TYPE OF APPENDICITIS	MC BURNEY INCISION			OTHER INCISIONS (R. RECTUS, MIDLINE, ETC.)		
	CASES	DEATHS	MORTALITY (%)	CASES	DEATHS	MORTALITY (%)
Unruptured	654	2	0.3	945	11	1.2*
Perforated	93	10	10.8	240	43	17.9
Abscess	78	5	6.4	162	9	5.6

*There is a significant difference between 0.3 and 1.2 per cent.

mortality rate. The McBurney incision is contrasted with all other types (all but a very few of the others being right rectus or midline). The table shows results consistent with earlier comments in this paper: no overwhelming advantage is shown for the McBurney incision. In acute unruptured appendicitis there is a definite edge and in acute perforated appendicitis there is an apparent edge in favor of the McBurney; in appendical abscess there is an apparent slight edge against the McBurney. These differences are not striking for the size of the series involved.

If, however, the acute unruptured appendicitis cases are lumped with the perforated ones (Table XIX) there is a significant statistical advantage shown for the McBurney incision. It is reasonable to place them together and consider abscess separately, because usually appendical abscess can be diagnosed beforehand and an incision accurately placed over it for drainage. In the other two groups, which are not infrequently confused preoperatively, localization is less accurate and the operative problem is identical: to remove the appendix with the least possible disturbance of the rest of the peritoneal cavity.

TABLE XIX. ANALYSIS OF DEATHS FROM APPENDICITIS—COMPARISON OF INCISION AND MORTALITY (BASED UPON ABDOMINAL DEATHS)

	MC BURNEY INCISION			OTHER INCISIONS (R. RECTUS, MIDLINE, ETC.)		
	CASES	DEATHS	MORTALITY (%)	CASES	DEATHS	MORTALITY (%)
Combined groups of unruptured and perforated appendicitis	747	12	1.6	1,185	54	4.6*

*There is a significant difference between 1.6 and 4.6 per cent.

Relation of Drains and Mortality.—Table XX portrays the effect of both drainage and incision in acute unruptured appendicitis. One interesting fact is brought out: if one decides to place a drain in a patient with acute unruptured appendicitis (a maneuver which we now deplore) there is no significant increase in the mortality rate if the McBurney incision is used; in other types of incision there is a significant increase in mortality with drainage. This is a reasonable finding when one reflects that a medially placed drain can produce

TABLE XX. ANALYSIS OF DEATHS FROM APPENDICITIS—COMPARISON OF DRAINS AND INCISION IN ACUTE UNRUPTURED APPENDICITIS*

	MC BURNEY INCISION			OTHER INCISIONS (R. RECTUS, MIDLINE, ETC.)		
	CASES	DEATHS	MORTALITY (%)	CASES	DEATHS	MORTALITY (%)
Drained	88	1	1.1	266	10	3.7†
Not drained	566	1	0.2	679	1	0.1
Total	654	2	0.3	945	11	1.2

*Based upon abdominal deaths.

†There is a significant difference between 3.7 and 0.1 per cent.

TABLE XXI. ANALYSIS OF DEATHS FROM APPENDICITIS—COMPARISON OF MORTALITY IN DRAINED AND UNDRAINED CASES*

TYPE OF APPENDICITIS	DRAINED†			NOT DRAINED		
	CASES	DEATHS	MORTALITY (%)	CASES	DEATHS	MORTALITY (%)
Unruptured	354	11	3.1	1,245	2	0.2
Perforated	291	52	17.8	42	1	2.4

*Based upon abdominal deaths.

†The greater mortality in the cases in which drainage was done is statistically significant.

more dissemination of infection in the peritoneal cavity than one placed laterally. One assumes that the two cases in which drainage is carried out are of comparable severity.

This vexing problem of when to drain is further dealt with statistically in Table XXI. The lesson in these figures does *not* lie in the fact that more patients die in whom drainage was carried out, than do those in whom drainage was not done; it is always argued, correctly, that the worst cases are the patients in whom drains are usually employed, and it is no surprise to see a greatly increased mortality rate in those drained. What is worthy of note is the low mortality rate in the perforated group closed without drainage; it proves that patients properly selected do not require drains in order to get well. This group of perforations (presumably the ones with least soiling of the peritoneal cavity and the best risk patients) may be considered roughly comparable to the worst group of unruptured appendicitis (those presumably drained). If perforated cases can be so well selected that the mortality rate stays below 3 per cent, the implication is inescapable that there will be practically no cases in the unruptured group which will require an intra-abdominal drain. The figures naturally do not prove that the drain was responsible for death when used in unruptured appendicitis, but at least they show that the drain failed to prevent death.

The trend toward tight closure in unruptured appendicitis is shown in Table XXII; when this is contrasted with the essentially unchanging general

TABLE XXII. ANALYSIS OF DEATHS FROM APPENDICITIS—MORTALITY AND DRAINAGE BY FIVE-YEAR PERIODS IN ACUTE UNRUPTURED APPENDICITIS

YEARS	CASES	PER CENT DRAINED	MORTALITY (%)
1913-1920	294	42.5	1.4
1921-1925	315	36.5	0.3
1926-1930	305	15.7	1.3
1931-1935	283	17.2	1.4
1936-1940	402	4.9	0.3

*Based upon abdominal deaths.

mortality rate over the years for this same group it can be seen that this policy has not affected the mortality adversely.

SUMMARY AND CONCLUSIONS

The failure of improvement in mortality figures for patients with acute appendicitis treated at the Peter Bent Brigham Hospital from 1913 through 1940 has stimulated a detailed study of the 106 fatalities occurring during this period. Emphasis is placed upon the importance of pathologic examination of the appendix in obtaining accurate statistics, and criteria are given for grouping cases as acute unruptured appendicitis, acute perforated appendicitis, and appendical abscess. Attention has been focused upon the 80 operative cases in which death of the patient was directly attributable to progressing appendicitis or its specific complications.

Delay in operation is shown to be a major factor in fatal cases. Sixty-seven of the 80 patients were operated upon forty-eight hours or more after the initial symptom. Fifty-eight patients were operated upon within six hours of reaching the hospital, but hospital delay of more than six hours because of an uncertain diagnosis took place in 16 cases. It is suggested that there be prompt operation when the differential diagnosis lies between acute appendicitis and some other condition such as acute salpingitis in which operation is not definitely contraindicated. The consequences of delay (whatever the reasons may be) are reflected in the fact that at the time of operation 53 patients had acute perforated appendicitis, 14 had appendical abscess, and only 13 had acute unruptured appendicitis. There were only 6 fatalities in patients operated upon within thirty hours of onset; of these, 5 had perforated appendicitis. It is likewise worthy of mention that 49 of 80 patients definitely received cathartics.

Fifteen patients had undrained residual abscesses at the time of death. Such abscesses should be specially sought for in patients not improving after two weeks from the onset of the disease. Ten patients died of severe ileus or mechanical intestinal obstruction; prompt preventive measures, or well-timed operative intervention might have saved some of them. Three patients died despite "adequate" dosage with sulfonamides; they are cited as proof that the management of acute appendicitis is complex and has not been solved by chemotherapy.

Statistics based upon the 80 cases give a slight advantage for the McBurney incision. Statistics likewise vindicate the trend in recent years toward closure without drainage, including selected cases with perforation.

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TECHNIQUE AND RESULTS OF PRIMARY AND SECONDARY PULL-THROUGH OPERATION AFTER REMOVAL OF TUMORS OF THE RECTUM AND RECTOSIGMOID

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DURING the past twenty-two years, I have devoted much attention and energy to the study of the problems of rectal surgery. At Hochenegg's clinic in Vienna I was entrusted with the follow-up examinations of over 1,000 rectal operations and I have had the opportunity of performing many hundreds of rectal operations myself. I have reported in many publications my experience dealing with rectal carcinoma, its operative treatment, and operative prospects and results.

Two major principles stand out clearly if one views the matter under the aspect of the future development of rectosigmoid surgery.

Anyone interested in the surgical approach to carcinoma of the rectosigmoid, which yields the best operative end results of all types of carcinoma amenable to surgical measures, should be familiar with any typical operation devised for this purpose; he should carefully make his plan and weigh the chances with due consideration of the individuality of the case as well as the site and spread of the tumor.

The technical methods most commonly practiced are: (1) The radical dorsal operation (Lockhart-Mummery), (2) rectal extirpation by the extended sacral method developed on the basis of that devised by Kraske and Hochenegg (Mandl-Goetze), and (3) the one-or multiple-stage abdominodorsal operation (preference to be given to the one-stage method [Miles]).

In the treatment of anal carcinoma which is an especially malignant tumor usually, it is often necessary to resort to electrosurgery, a detailed and comprehensive study of which has recently been published by Roffo and Carranca. It would exceed the extent of this article to discuss the pros and cons of all methods, particularly as they are sufficiently known.

Any method sacrificing the sphincter and where it might be preserved without endangering the radicality of the operation must be considered an imperfect one. The progress of rectal surgery is marked by the now possible combination of a very high degree of radicality with preservation of the sphincter, that is, restoration of continence.

Viewing the matter from a psychologic viewpoint, it should be borne in mind that patients may find colostomy very compatible with business and their other duties. They usually adjust their habits and diet to the situation according to their own experience, and achieve quite satisfactory control over bowel movements, which may naturally be still further improved by various devices. The great majority, however, of all those suffering from incontinence or, even more so, those with an artificial anus, whether abdominal or dorsal, easily fall a prey to depression, are barred from any kind of social activity and, for the greatest part, are incapacitated. It is common knowledge that patients who may not even fear recurrences commit suicide for the simple reason that life has become unbearable with an artificial anus. This is even more likely to

occur if they are in an unfortunate financial position or particularly hampered in their professional career. I have, therefore, adopted it as an unshakable axiom that radical operation for rectal carcinoma, even if performed with the greatest possible degree of technical skill and even if the results are permanent, is imperfect unless an attempt has been made to preserve continence or, at least, to give the patient the well-founded hope, with a clear conscience, of its future restoration. The foolish sacrifice of sphincters is barbaric and everything should be done to substitute these methods by others guaranteeing the preservation of the sphincter.

There can be no doubt that the maintenance of sphincteric function involves greater risks both for the patient and for the surgeon than does simple radical operation. Aftertreatment is, moreover, more inconvenient and the prolonged stay in the hospital must be followed by weeks or even months of ambulant treatment.

There is no denying that preservation of the sphincter may occasionally be impossible. If, for example, the tumor, of whatever type it may be, is itself imbedded in the sphincteric or anal portion, the radicality of the operation would greatly suffer by any attempt to proceed conservatively—a risk that cannot be taken. In approximately 25 per cent of all cases of rectal carcinoma the idea of preserving sphincteric function must be abandoned from the outset. Here the establishment of a sacral anus, at as low a level as possible, ensures relative continence provided there is adequate scar shrinking and control by innervation of the gluteal musculature, an aim that can also be attained by the “gluteal anus” as devised by Petermann.

The preservation of sphincteric function in malignancy of the rectosigmoid has, up to quite recently, received little attention in the Anglo-American literature. Earlier suggestions referring to that point (Maunsell, 1892, Weir, 1901) were recently reviewed by Wangenstein, but it seems that this has not aroused much attention either.

The discussion was recently reopened by Babcock and Bacon, who advocated preservation of the sphincter if the tumor is within at least 7 cm. from the sphincter ani. Wangenstein (1943) critically scrutinizing the problem, believed that methods for the full restoration of sphincteric function might very well be worked out, and that “re-study of the Kraske-Hochenegg sacroperineal methods with special attention to an abdominal method . . . with preservation of the sphincter is in order.” He referred to two papers (Wilensky, 1942, and Pannett, 1943) dealing with the preservation of the sphincter in abdominoperineal operations, the originals of which are, however, unfortunately not accessible to me. Finally, the Agenda of the Ninth National Assembly of the International College of Surgeons, in Philadelphia, 1944, announced that Bacon and co-workers would report on “Surgical Treatment of Rectal and Sigmoid Cancer Without Colostomy With Sphincter Muscle Preservation” and A. A. Berg on “The Preservation of Sphincter Ani in Radical Operation for Cancer of the Rectum.” In his book, moreover, Bacon referred to the pull-through method, adding a brief description.

As far as we know, the French literature does not contain many contributions to the question of the preservation of sphincters (see Bergeret). Cuneo, Seneque, and Zagdoun practiced the method of circular suture of the rectum after “perineal resection” with preservation of sphincters. Years ago I attended the excellent performance of the pull-through operation by Hartmann and Victor Pauchet.

In the German literature, methods advocating the preservation of continence are fairly numerous: (1) by circular suture (Kraske) after resection of the tumor from its continuity within the sacral wound and (2) by the pull-through method devised by Hochenegg, while (3) Hochenegg's "invagination method" has scarcely been practiced.

It is of particular importance to bear in mind, provided the tumor lies at an adequate distance from the anus with no involvement of the sphincteric portion itself, that the preservation of the sphincter has by no means an unfavorable influence on the ultimate result of the operation—a point constantly stressed by me after conscientious study of 1,300 cases with inclusion of the entire literature. I have emphasized this point in numerous publications and the opinions of only a few other authors which could not be taken into consideration on these earlier occasions remain to be added.

Goepel described a two-stage abdominosacral method, the second stage terminating in the pull-through act (Hochenegg). In one of his cases, exteriorization through the anus of a length of 7 to 8 cm. of the large intestine could be performed without gangrene supervening.

H. Kraske paid special attention to the preservation of the sphincter. If the intestinal portions at one's disposal are short, a circular suture is made in the dorsal wound while the normal procedure is the pull-through method. Where the sphincteric portion must be sacrificed, the distal end of the rectum is used for the construction of a gluteal anus. Full continence was reported by this author in 50 per cent.

Petermann, the inventor of the gluteal anus, also advocated preservation of the sphincter wherever possible. He gave preference to the pull-through method and reported continence in 50 per cent of his cases.

Nordmann also maintained that in the absence of sphincteric involvement all available means should be mobilized to preserve sphincters (1) by employing the method devised by Kuettner with sacral exteriorization and subsequent amputation of the tumor with secondary suture or (2) by the pull-through method (Hochenegg) without distention of the sphincter or excision of mucous membrane. He pointed out that healing of "circular sutures" after primary resection of the wound was very rare.

Dannhaeuser, in connection with the dorsal as well as with the combined method, laid particular stress on the preservation of the sphincter and with the customary methods he reported satisfactory results in 77 per cent of cases.

Hybinette of Stockholm, sacrificed the anal portion only if the site of the carcinoma was a very low one. For those situated higher up, he recommended as the method of choice the abdominodorsal approach, pulling the colon down through the anus. He preferred this method to circular suture.

From the foregoing it appears that no surgeon earnestly concerned with the preservation of sphincteric function deems the methods advocated by him for this purpose a danger to the radicality of the operation for carcinoma of the rectum or sigmoid.

A great step forward in this respect was marked recently by the microscopic studies published by Westhues. This author pointed out that: (1) Carcinomatous metastases, whether in connective tissue or in lymph nodes, which are on the level of the carcinoma itself or higher up are, for all practical purposes, confined to the neighborhood of the superior hemorrhoidal artery. (2) Beyond the level of the tumor itself, no involvement of the intestine and especially

the pericolic connective and lymphatic tissue takes place. This was, in some measure, verified by R. S. Grinnell who pointed out that "the main extramural lymph spread is upward along the superior hemorrhoidal vessel." For no more than one out of seventy-five specimens which were carefully studied could Grinnell report downward spread.

Seefeld and Bargen, after reviewing 100 cases of rectal carcinoma, maintained that the significance of metastases of this type of carcinoma to veins and nerves was practically as great as that to the lymph drainage area (47:20:30). This fact, however, does not alter our attitude toward the problem of rectal carcinoma. Our practical approach to the question has thus received what one might call theoretic support which is today generally acknowledged.

The preservation of the sphincteric portion by no means always implies restoration of continence. There is no doubt that with the methods so far at our disposal it is in but a limited percentage of cases that we may succeed in doing so. My personal experience, as well as the literature referring to that point, proves thus far that the safest way to ensure continence is by the pull-through method devised by Hochenegg in 1888, which is also to be preferred to Kraske's method consisting in circular suture after resection of the carcinoma by the dorsal approach. This is also clear from an anatomic viewpoint, as a circular suture between two portions of intestine can be approximated only if both parts are well covered with serosa.

This "circular suture" within the wound, as a rule, implies the union of one serosa-bearing part (the proximal extremity of the mobilized sigmoids) and one with no serosal covering (the peripheral extremity of the rectum at the level of the ampulla or sphincter). In view of what we know about intestinal sutures in general since the time of Lembert and Jobert (1824 and 1826, respectively), no smooth healing can be expected under these circumstances.

This is also the drawback of a method recently introduced by Dixon, Dunphy, and associates, the so-called "anterior resection." Apart from the viewpoint of radicality and blood supply, the removal of recto-sigmoid carcinoma from below the Douglas pouch by pushing the tumor into the abdominal cavity makes it questionable whether the peripheral portion of the intestine is still covered by serosa. Otherwise the procedure is certainly doomed to failure.

It would be of interest to know in what percentage of cases continence can be restored after preservation of the sphincter. According to my personal experience, healing by first intention occurs in but 20 per cent of cases after Kraske's circular suture. By an additional operation one may improve the operative results up to from 40 to 50 per cent, while in the others fistulas are likely to form, which confront the patient as well as the attending physician with the tedious task of a prolonged and inconvenient aftertreatment.

Regarding Hochenegg's pull-through method, it should above all be pointed out that even after preservation of the sphincter it can only be employed in a certain percentage of cases and under very strict provisions. This percentage may amount to from 30 to 40 per cent of all those cases in which the sphincter has not been sacrificed. According to my studies in 1929, primary restoration of continence was possible in 60 per cent. After an additional operation, positive results could be increased to 65 per cent, and although this is a relatively small percentage it is, nevertheless, worth trying.

In the following, the technique of the so-called "primary pull-through method" of Hochenegg is described and suggestions are made as to how, according to my personal experience, to bring it to a successful termination, since

nowhere in the literature has the method been dealt with in detail. I am also giving a description of the so-called "secondary pull-through method" which may allow a greater number of patients to have continence restored.

PRINCIPLES

I. The Primary Pull-Through Operation

A. Radical Operation.—There can be no doubt that with the combined abdominosacral or abdominodorsal and also by the purely dorsal method (sacral, extended sacral method, Mandl-Goetze) as much of the colon can be mobilized as is necessary to perform the pull-through through the intact sphincter. At the European clinic where I formerly worked, I employed this method in several cases after combined abdominosacral operation (see Case 1), while here in this country I have had only one such case.

B. Precondition.—A precondition for the smooth healing after pull-through operation is the preliminary construction of colostomy. In the past few years I have preferred the method of establishing preliminary colostomy in the transverse colon approximately a fortnight prior to radical operation. Only strict avoidance of contamination to the dorsal wound, where the operation for restoration of continence takes place, ensures success. That the pull-through operation was successful in a few exceptional cases in spite of no preliminary colostomy being made is of no importance. When colostomy is performed, the abdominal organs should be inspected (length of sigmoids, width of mesosigmoids).

C. The Sequence of the Various Manipulations in Radical Operation.—It may be concluded from publications and suggestions in the literature that it is worth while to point out that the pull-through manipulation should follow as the last in the sequence of events for the following reasons: Only after radical operation has been completed is it possible (1) to form an opinion on the nutritional condition of the peripheral intestinal portion, (2) to ascertain whether the length of the intestine will suffice to undertake the pull-through, and (3) for reasons of asepsis (see D).

D. The Technique of the Primary Pull-Through Operation.—After abdominal mobilization and ligation of blood vessels, whether in a typical or atypical way, or after mobilization of the colon by the sacral approach, extensive portions of the tumor are exposed in the sacral wound. Shortly before closing the wound the surgeon must decide whether to proceed to the pull-through operation. The best guarantee for the success of this part of the operation is a well-developed vascular supply to the part which is to be pulled through, the most important criterion for which is the color of the bowel after mobilization. Today we know for certain, as a result of numerous studies (the latest publication on that point probably being that by Singleton), that it is at the site of ligation (Sudeck's "critical point") that the last full anastomosis between the superior hemorrhoidal and the inferior mesenteric arteries by way of the sigmoidal artery can be expected and it is often, although not invariably, possible to take this into consideration when making the plan for the operation. However, in the majority of cases, practical considerations demand grossly anatomic mobilization up to a degree until as much of a well-supplied bowel is at our disposal as is necessary to be pulled through the sphincter. As a general rule, exceptional width of the mesosigmoid already suggests that a sufficient length of sigmoid will be available for the further procedures. Roentgenologic studies prior to operation or inspection of the parts exposed during colostomy will give a helpful idea on the length of the sigmoid.

Apart from the color of the bowel wall, inspection of the small, subserous blood vessels of the portion used for the pull-through is a valuable aid. Pulsation can be visualized by painting with a 6 per cent phenol solution.

To avoid failures, no efforts should be spared to make certain that the bowel used for the pull-through is actually of normal vitality. It should, therefore, be carefully covered with warm cloths and watched for the appearance of any color change, as it is routine, for example, in operations for incarcerated hernia.

1. *To ensure the vitality of the bowel*, the care of the wound through which it passes is of great importance. It is imperative that within the sacral wound the intubated intestinal segments be approximated by interrupted sutures (Fig. 1) and the bowel, as far as possible, be covered by soft parts. This provides the best protection, for the serosa does not tolerate well contact with strips of gauze. The secretion should be aspirated by rubber drains. Spraying with sulfanilamide, according to our latest experience, apparently does not reduce the vitality of the bowel and is further a valuable help in keeping the wound cavity clean.

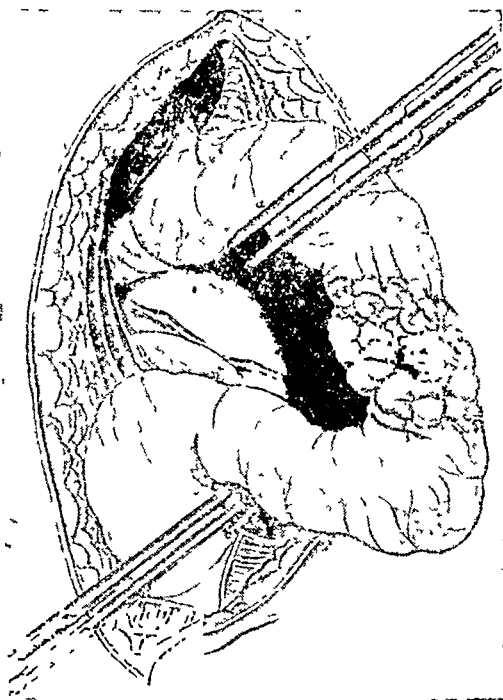


Fig. 1—Modification of picture given by Bacon. The tumor together with the rectosigmoid has been mobilized by posterior approach or by abdominodorsal method. The Douglas sac has not yet been closed. After its closure and after further mobilization an attempt will be made to approximate segment *a-b* (after resection of the tumor between the clamps) to *a'-b'*. If this is possible without tension and the blood supply remains normal, the "pull-through" may be envisaged.

2. *How is the sphincteric portion attended to?* Manipulations on the sphincteric portion should not be started before the operation on the proximal part is completed and the Douglas pouch sutured again. No dilation of the sphincter is necessary because of its relaxation after general or lumbar anesthesia (the latter being preferred by us).

Hoehenegg suggested removing the mucous membrane of the sphincteric segment prior to undertaking the pull-through, as is customary in the Whitehead operation for hemorrhoids (Fig. 2). Disinfection of the sphincteric portion is done by repeated painting with tincture of iodine (10 per cent) from

the anus, following which the clamp holding the sphincteric portion is removed (*a* to *b*) and the mucous membrane eventually extirpated. All these manipulations need not imply the slightest injury to the internal sphincteric muscle. Kocher advocated leaving the mucous membrane intact, a method attended by advantages but by disadvantages, too. Control of hemorrhage after extirpation of the mucous membrane is time consuming and often difficult, requiring a very high degree of accuracy. On the other hand, aseptic conditions are more easily maintained if the mucous membrane is removed, because effective disinfection of the sphincteric mucous membrane is no easy task, and the mucosa, if it is left in place, naturally continues its secretory activity and the presence of secretion between the sphincteric mucosa; the serosa of the part of the bowel which has been pulled through provides a serious obstacle to healing. Experimental and microscopic studies (Gara and Mandl) showed that the growth of adhesions between the mucous membrane and the serous surface occurs either very late or not at all. Where mucosa and serosa are in contact, the glandular structure of the mucosa is preserved while the serosa becomes subject to necrosis. There is, moreover, the possibility that mucous cysts may form and the main factor in the production of fistulas is the attempt of the secretion to find an escape. Removal of the sphincteric mucous membrane prior to the pull-through operation is, therefore, commendable (see Case Reports).

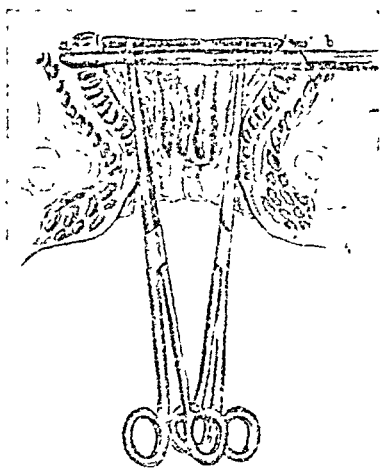


Fig. 2.



Fig. 3.

Fig. 2.—Manipulations on the sphincteric segment. The lowest clamp (see Fig. 1) is left in place until after disinfection of the sphincteric portion and is then removed. Following this, the mucous membrane is removed by grasping the clamps and pulling them directly through the sphincter, under strict control of hemorrhage and avoidance of injury to the muscles.

Fig. 3.—Primary pull-through completed. The Douglas sac is closed. The segment of bowel which has been pulled through shows no tension and is of normal appearance. Where the two bowel segments are invaginated into each other, we have placed interrupted sutures (*a*). The bowel has been pulled through far beyond the anus and will be amputated several days later. At its base, note stitches between the skin of the anus and the external layers of the bowel.

Another method has been practiced at my department for a number of years now. The entire sphincteric segment is sharply divided by a vertical incision, folded apart, the mucosa disinfected, and then extirpated in toto. The peripheral colonic segment is then placed into the wound and the vertical incision closed by suture throughout all its layers. No doubt this method allows the whole operative procedure to be conducted under the guidance of the eye,

but it has nevertheless been abandoned by us in view of the frequent occurrence of infection, which forestalls any possibility of restoring continence later.

3. *The bowel segment pulled through the anus* should protrude beyond it (Fig. 3), and any shortening is inopportune since it is likely to cause shrinkage or necrosis of the colonic segment. From the small number of illustrations available in the literature so far published, it can be concluded that the bowel segment used for the pull-through is severed just above the anus and approximated to it by circular suture. In my opinion, there is nothing to recommend such methods. Our procedure is to fix the base of the protruding bowel between skin and serosa with interrupted sutures. The sutures placed within the wound, in addition to those between the sphincteric segment and the other part, are, as a general rule, sufficient to prevent the bowel from slipping back (Fig. 3).

The portion protruding beyond the anus is *later* amputated by electrocautery.

E. Aftertreatment.—Because as the operation has, as a rule, been preceded by colostomy, the evacuation of feces involves no problem at all. If, for some reason, no preliminary colostomy has been made, the patient should, after the customary emptying of the bowel, be given eight drops of tinctura opii three times per day for the duration of eight days after operation. On the tenth to twelfth day, bowel movement should be encouraged by oily laxatives. As a general rule, unless there is a special reason, digital exploration should be postponed until after the tenth day. After the lapse of a fortnight, it is even useful for the relief of the mild degree of stenosing usually present at the pull-through point. Even bougies may be used. Repeated examinations are indispensable, particularly as the colostomy can be closed only after the peripheral wound has healed satisfactorily and there are no fistulas. On the first few days, following operation, voluntary innervation of the sphincter cannot be expected, or at least only in a very superficial manner. Systematic exercises may, however, improve conditions remarkably. They are of outstanding importance for the rapid restoration of continence.

F. Complications.—

1. *Infection:* Infection, if it occurs, is usually due to gangrene of the bowel segment pulled through the anus. This is also the point where the danger of toxemia must be considered (sulfanilamide prophylaxis). A positive result of the operation can, in such a case, no longer be expected. The wound should be exposed and typical wound treatment instituted. The fistula thus established may later be closed.

2. *Fistulas:* There is always a certain percentage of cases in which small fistulas occur (see Case Reports). Unless there is gangrene of the bowel, the majority of them are amenable to conservative measures (rinsing with disinfectants, warm hip baths, postponement of the closure of the colostomy). Generally, they develop at the posterior circumference of the bowel, which has been pulled through, and open into the sacral wound.

3. *Slipping back of the bowel segment pulled through the anus:* The segment pulled beyond the sphincteric portion may become subject to necrosis and is then spontaneously, although gradually, cast off up to a certain height. Fistulas are rather common, but the internal suture between the two parts (Fig. 3) may nevertheless ensure smooth healing with satisfactory sphincteric function. Where this occurs, stenosing may (although it should not) take place which requires systematic dilatation after the wound has healed.

II. The Secondary Pull-through Method

The secondary pull-through method must be resorted to in two instances:

A. During radical operation for rectal carcinoma, when the primary pull-through operation is envisaged but the length of bowel possible to mobilize proves insufficient or its peripheral segment of poor vitality, the operation must be terminated by the construction of a sacral anus. The sphincteric portion is nevertheless spared (Fig. 4) and its upper extremity closed by a firm suture.

B. Either the primary pull-through method or circular suture (Kraske method) is originally performed, but because of infection, partial gangrene, or slipping back of the bowel, a sacral anus forms by itself. The sphincteric portion is left in place, as it is in accordance with the whole plan of the operation

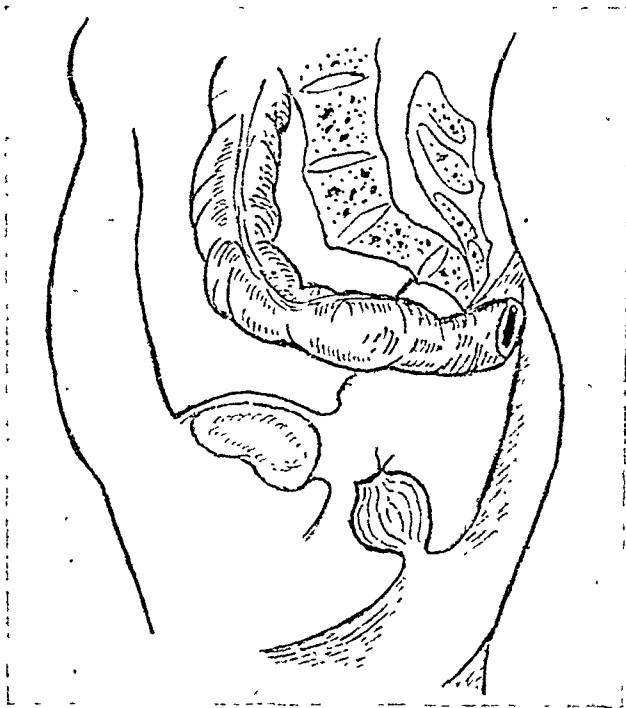


Fig. 4.—Diagram of sagittal cross section after mobilization of the rectosigmoid and construction of a sacral anus since mobilization of a considerable length of well-supplied bowel down to the sphincter had not been possible. After suturing of the Douglas pouch, a sacral anus was, therefore, made. The sphincteric portion (see Fig. 1, *a-b*), held by a clamp, will be ligatured by a strong thread and buried in the depth.

In the course of time the sacral anus of the proximal segment may develop prolapse which Weil used, after invagination so that the mucosal covering was again on the inside, to perform a secondary pull-through operation. Any surgeon may be confronted with such an emergency. Thus Hochenegg's archives contained the records of a few successful operations of this kind. Beyond that, I could show that this prolapsing could be *artificially* promoted and a secondary pull-through operation thus made possible. (See References, Mandl.)

First of all, one should realize what the anatomic preconditions are that lead to prolapse. There are (1) insufficiency of the soft and bony pelvis floor, (2) low pouch of Douglas, (3) insufficiency of the rectal attachments, (4) increased abdominal pressure by exaggerated activity of the abdominal musculature. No doubt, the soft as well as the bony pelvis floor loses some of its efficiency after radical operation for rectal carcinoma and resection of the coccyx and sacrum.

If the pouch of Douglas reaches down to a low level, the cul-de-sac is opened during radical operation, the bowel extracted from the small pelvis, and the suture placed as low as possible, a procedure likely to produce prolapsing. There can be no doubt that extensive mobilization of rectum and colon is attended by the risk of damaging the rectal attachments. If the patient is further encouraged to make systematic exercises ("as though he were going to have stools"), increasing the intra-abdominal pressure by pressing, every day for several hours, everything is done to promote prolapsing of the sacral anus. Actually, a method has been developed on the basis of these considerations which may be described as "the artificial production of prolapse from sacral anus," facilitating the secondary pull-through operation. (Fig. 5.)

A typical circumcision is made around the prolapse, the external segment invaginated with the mucosa on the inside (like a glove turned inside out), which provides the length of bowel necessary for the pull-through manipulation. If the pouch of Douglas gets punctured during this procedure it is sutured in the same way as during the primary operation. As a rule, however, one encounters only adhesions in which blood vessels have to be ligated. An incision is then made through the soft parts, stretching from the sacral anus to just above the normal one (Fig. 5, *a* and *b*). The sphincteric segment left in position during the main operation and ligated at its proximal extremity, as a rule, completely grows together, so that a circular excision (Fig. 5, *c*) has to be made before the prolapsing portion can be pulled through.

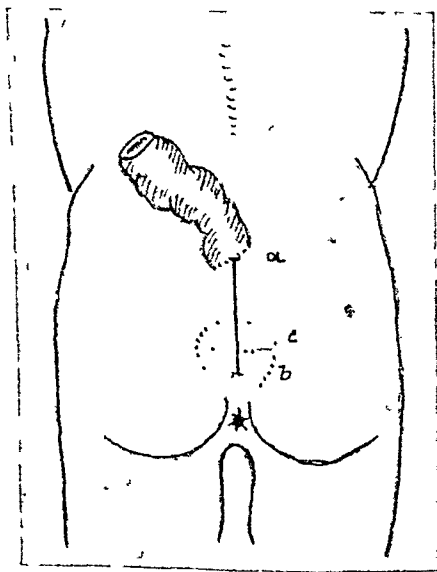


Fig. 5.

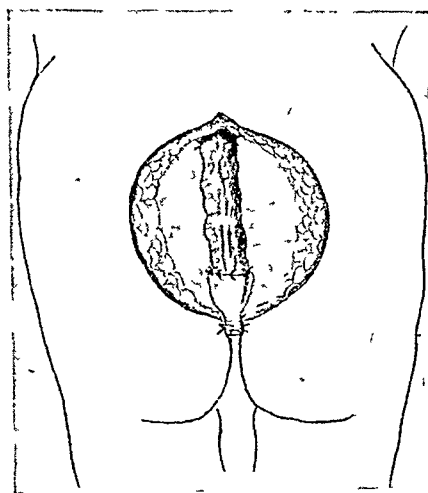


Fig. 6.

Fig. 5.—Secondary pull-through method. A few months after radical operation the sacral anus has developed into a prolapse which, in the diagram, has been turned upward. The procedure is, after circumcision at its circumference, to turn it inside out, so that the mucous membrane is now on the inner side, following which an incision is made from *a* to *b*, that is from the base of the prolapse to just above the natural anus. The roof of the sphincteric segment, which is left in place, usually grows together and has to be resected by circular excision (*c*), following which the prolapse can be pulled through the soft parts and the sphincter.

Fig. 6.—Diagram of completed secondary pull-through operation. Note inside suture at the bowel and those on the outside similar to Fig. 3.

It is interesting to note that the degeneration of the mucosal lining of the sphincteric portion owing to many months of idleness provides a much less formidable obstacle to its healing smoothly to the serosal covering of the bowel which has been pulled through, than the conditions created by primary pull-

through operation. The excision of the mucous membrane in the secondary method, which is not done before several months have elapsed following radical operation, is not, therefore, an indispensable measure. The operative technique is illustrated by Figs. 6, 7, and 8.

I have reported upon a number of successful operations according to this method in the course of the past few years. By others it has only been mentioned without statistical data being added (Goetze). Only my former collaborator, Ebner, mentions the fact that exercises in abdominal pressure were routine at the Second Surgical Department of the University Clinic in Vienna, and that, as a consequence, the number of secondary pull-through operations could be considerably enlarged. Ebner tried to carry the idea even farther. Careful studies of the abdominal pressure by means of colpeurynters introduced into the ampulla recti revealed quite high values (up to 190 mm. Hg). The mean values were found highest in defecation position, lower in knee-elbow position. It is, therefore, pressing "as though to have stool," recommended by me in 1925, that is the most successful method to obtain prolapse. In the great number of patients who, after resection of the rectum, had been encouraged to make systematic abdominal exercises, Ebner distinguished, one year after primary operation, three types: (1) Those in whom prolapse had occurred from a wide sacral anus as a suitable aperture, (2) those in whom no prolapse had occurred but who had a sacral hernia. In such cases, the sacral anus is narrow and scarred, the sigmoid and mesosigmoid long, which could be verified by x-rays and digital examination. and (3) those in whom neither prolapse nor hernia has occurred.

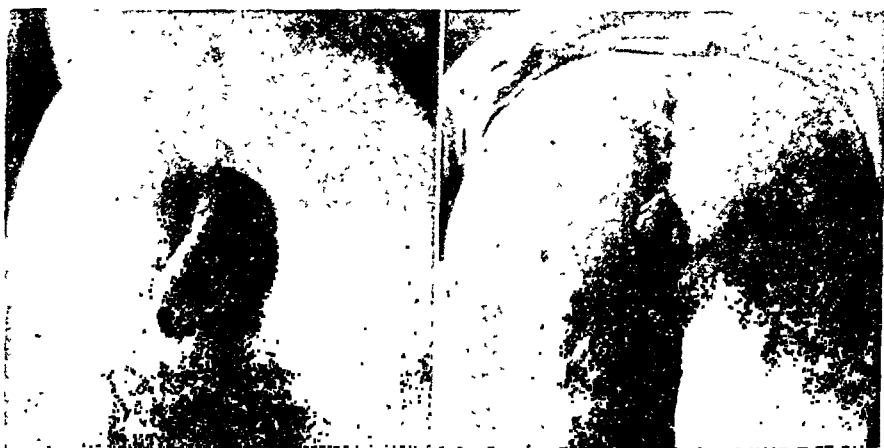


Fig. 7.

Fig. 8.

Figs. 7 and 8.—Patient with artificial prolapse from sacral anus before and after secondary pull-through operation (From Felix Mandl: *Arch. f. klin. Chir.* 136: 479, 1925.)

I have performed the secondary pull-through operation on all three types without discrimination. It is clear, however, that types 1 and 2 are more suitable objects for this operation. Ebner reported eight successful secondary pull-through operations in the presence of hernia without prolapse (type 2). Type 3 naturally presents difficulties. The scar tissue has to be resected and the stenosed sacral anus reamputated. Ebner reported success in two such cases. Unfortunately, no exhaustive statistical data covering the whole of his material are available.

Be this as it may, the method advocated by me, consisting in the establishment of an artificial prolapse from the sacral anus, providing a new way to pre-

pare the secondary pull-through operation, is a very simple measure. Although it is very distasteful to the patient, for the duration of many months, to put up with having two artificial ani (one in the transverse colon through which the feces pass and another in the sacral region from which, providing a normal function of the first, only mucus escapes), skillful persuasion will help him over this uncomfortable and inconvenient period.

During the pressing exercises, the patient should be warned forcibly to press back the abdominal anus with his hand, since otherwise the prolapsing may occur in the abdominal rather than in the sacral anus. Our experiments with a view to promote prolapsing by means of a cupping glass were also rather successful.

THE CLOSURE OF THE COLOSTOMY

Since in my opinion success or failure of primary or secondary pull-through operations to a high degree depends on the preliminary establishment of a colostomy, a few remarks on this operative procedure seem indicated. It has recently been pointed out that the radical removal of rectal carcinoma should be done in one stage. If the sphincter, for some reason, cannot be spared, I also practice this method, preferring the one-stage operation according to Miles, especially since it is a common experience that patients may be as severely taxed by colostomy as by radical operation. Nevertheless, I am convinced of the necessity of constructing a colostomy prior to proceeding to the pull-through operation. The surgeon should not forget, however, that when making a colostomy it is his concern to provide for its later closure, which should be as simple as possible. In this respect the "double-barrel colostomy" devised by Mikulicz is a very suitable method. If it is carried out correctly, its closure by a Mikulicz clamp, which is introduced into the two limbs of the bowel, is a very simple procedure. Crushing of the spur by means of the clamp saves, in the majority of cases, major operative measures. Parts of the colonic mucous membrane protruding over skin level are removed by electrocautery, a procedure which must be repeated again and again until the skin grows over the two foramina. If the peripheral bowel is pervious, operative closure of a colostomy, implying opening of the peritoneum, is very rarely necessary. The most instructive illustration of the method, which I have been practicing for many years, and which is in agreement with Mikulicz's directions, is contained in a paper by Moskowicz. Where this method is impracticable, I am using, for the intra- or extraperitoneal closure of a colostomy, that described by Bacon.

The method outlined here has undoubtedly contributed much to the possibility of restoring continence in a far greater number of patients than was originally thought possible. Its adoption by wider circles will give surgeons the necessary experience to improve the results even further.

MY OWN MATERIAL

A large part of my operative records have been lost owing to political complications, but my publications continued up to the year 1940. Where I am working now and have but limited material at my disposal, I have nevertheless performed fifty-four radical operations for rectal carcinoma (from 1939 to 1944) in seventeen patients (that is 31.4 per cent) in whom I attempted to maintain continence primarily or to restore it, after preservation of the sphincter, by a secondary pull-through operation. The records on these cases are *complete*, and give a good idea of the pros and cons and even dangers of the method.

Case reports are given as concisely as possible and no reference to malignograms has been included.

REPORTS OF CASES

I. Radical Operation for Rectal Carcinoma With Subsequent Primary Pull-Through Operation (Eight Cases).—Normal healing without formation of fistulas, by first intention, with complete restoration of continuity (seven cases) (Fig. 9).

Apart from one patient who died after radical operation followed by primary pull-through, there are seven cases at our disposal.

CASE 1.—The patient was a man of 60 years, operated upon in February, 1938 (in Vienna). The site of the tumor was about the pouch of Douglas and the combined abdomino sacral approach was used after preliminary construction of a colostomy. This was followed by a pull-through operation and healing occurred by first intention. In the course of the year 1939 the colostomy closed spontaneously. Follow-up examination in 1944 showed no recurrence and perfect continence.

CASE 2.—The patient, a man 39 years of age, was a physician. He had a tumor 15 cm. from the anus. Nov. 6, 1939, colostomy was constructed on the transverse colon. Nov. 21, 1939, extended sacral operation was done with primary pull-through. Dec. 25, 1939, there was operative closure of the colostomy followed by healing by first intention. The patient joined the British Forces in 1940 and is doing front-line service. He reports perfect continence.



Fig 9—Patient after primary pull-through operation. Healing took place by first intention, a fortnight after radical operation and after amputation of the protruding bowel.

CASE 3.—The patient was a woman, 50 years of age, with a tumor approximately 10 cm. from the anus. As she was very obese, no colostomy was made. May 20, 1940, extended sacral operation was done with primary pull-through and resection of 45 cm. of bowel. Healing occurred by first intention. Follow-up (August, 1944) showed no recurrence and perfect continence.

CASE 4.—The patient was a man of 33 years, with carcinoma 8 cm. from the anus. June 11, 1941, colostomy was made on the transverse colon. June 26, 1941, radical operation (extended sacral method) was followed by primary pull-through, 30 cm. of bowel being resected. Healing occurred by first intention. In January, 1942, the colostomy was closed. Follow-up (October, 1944) showed no recurrence and perfect continence, while the only complaint the patient had was of sexual impotence.

CASE 5.—The patient was a woman, aged 50 years, who had a tumor 8 cm. from the anus. Sept. 8, 1941, colostomy was constructed on the transverse colon. September 28, extended sacral operation was done with primary pull-through. Healing occurred by first intention. On Oct. 22, 1941, the colostomy was closed. Follow-up (May, 1944) showed no recurrence and continence was perfect.

CASE 6.—The patient was a woman of 45 years, with rectal carcinoma 12 cm. above the anus. June 3, 1939, colostomy was made on the transverse colon. June 18, 1939, radical operation (extended sacral method) with resection of 38 cm. of bowel (Fig. 10), was followed by primary pull-through. Healing occurred by first intention. Sept. 20, 1939, the colostomy was closed. The patient died Aug. 2, 1942. Autopsy record showed no local recurrences, large cerebral metastasis in the right frontal lobe, and others in the right suprarenal gland. Death was caused by the cerebral metastasis.

CASE 7.—The patient was a man, 44 years of age, with a polypous tumor 9 cm. from the anus. April 30, 1943, colostomy was made on the descending colon. May 21, 1943, radical operation (extended sacral method) was done with primary pull-through. Healing occurred by first intention. Two attempts to close the colostomy operatively failed. However, in December, 1943, it closed spontaneously. Follow-up (September, 1944) showed no fistula, no recurrence, some weakness of the sphincter which, although able to cope with normal stools, showed a certain deficiency if the stools became diarrheic.



Fig. 10—Development of sacral hernia from sacral anus. The sphincter had been preserved.

II. Primary Pull-Through Operation Followed by Fistulas, Their Response to Treatment and End-Results (Six Cases).—

CASE 1.—The patient was a woman of 66 years with a tumor 8 cm. from the anus. On Aug. 18, 1940, extended sacral operation was performed without preliminary colostomy, with resection of 20 cm. of bowel followed by primary pull-through. Recovery was complicated by urinary infection, pulmonary infarction, cardiac failure, and severe mental depression. Just above the normal sphincter a fistula had formed. Rectal examination showed that the bowel had slipped back. The patient was discharged Dec. 1, 1940, after all complicating symptoms had subsided. Although she still had a fistula from which, during defecation, a strip of feces the thickness of a match escaped, her condition was quite satisfactory, as there was a normally registered desire for stool and full continence. Treatment consisted in rivanol irrigation (1:2000) and warm baths. In December, 1941, the woman suddenly died, apparently from heart failure.

CASE 2.—The patient was a woman of 38 years, with a tumor situated at three finger widths above the pouch of Douglas. Nov. 25, 1943, a colostomy was made in the transverse colon, followed, Dec. 6, 1943, by extended sacral operation with resection of 20 cm.

of bowel and primary pull-through. The mucous membrane of the sphincter was left intact. The segment of bowel which had been pulled through slipped back and sacral fistula formed. The colostomy of the transverse colon did not function normally either, and feces passed through the lower colonic segment. A new colostomy was, therefore, made proximally to the original one, also in the transverse colon. As early as four weeks later, the sacral fistula closed. On digital exploration, it was found that there was a free communication between the sphincteric portion and the bowel which had slipped backed and there was neither stenosing nor any detectable defect. Even on pressure or rectoscopy, no internal fistulous opening was recognizable. However, before the colostomy could be closed, diffuse metastasizing occurred in the lungs (Oct., 1944) so that the plan had to be abandoned.

CASE 3.—The patient was a man, 48 years of age, with a tumor which could only be established on rectoscopy as lying at a distance of 18 cm. above the anus. Nov. 15, 1943, a colostomy was made in the transverse colon which, however, severely taxed the patient, who was suffering from angina pectoris and myocardial insufficiency. Dec. 31, 1943, extended sacral operation was done. The tumor was found at approximately three finger widths from the Douglas fold. Although the mesosigmoid was short, it was possible to resect 16 cm. of bowel up into the healthy tissue, and the sigmoid loop could be pulled through the anus (primary method). To shorten the operation, the mucosa of the sphincteric portion was left in place. The patient stood the radical operation better than the colostomy. A small sacral fistula developed which was improved by baths and rivanol irrigations, while its complete closure, under ambulant treatment, did not occur before May, 1944. By October, 1944, the patient had no fistula and the peripheral intestinal segment was in perfect order. Owing to his heart condition, the closure of the colostomy was postponed, the opening, however, shrinking more and more and as the patient informed us, no more than about one-third of the feces passed through it while the remainder left the bowel by the natural way, with full retention and normal sphincteric function.

CASE 4.—The patient was a man of 36 years, with a tumor about 16 cm. above the sphincter. Dec. 23, 1944, colostomy was performed on the transverse colon, followed, on Jan. 7, 1944, by radical operation (extended sacral method with primary pull-through). The mucosa of the sphincteric region was left intact. It was, however, possible to place a great number of sutures between the part of the bowel which had been pulled through and the sphincteric portion. Thirty centimeters of the bowel were resected. Recovery was normal, but a small sacral fistula developed which could be brought to closure by a four months' ambulant treatment. Follow-up examination (August, 1944) showed no recurrence and perfectly normal functioning of the peripheral intestinal portions. The patient was advised to have the colostomy closed to which he finally agreed in December, 1944. The patient was cured and discharged from the hospital with perfect continence.

CASE 5.—The patient was an extraordinarily obese woman of 47 years, with a tumor 8 cm. from the anus. No preliminary colostomy was made. March 11, 1944, extended sacral operation was performed with resection of 12 cm. of bowel. There was a hemorrhage from the sphincteric portion which had been deprived of its mucous membrane, which could, however, be arrested by tamponing. The hemorrhage did not cause her any harm, but owing to either the packing or the pressure of the hematoma, partial necrosis occurred in the intestine and two sacral fistulas developed. Healing under ambulant treatment was complete in August, 1944, although no colostomy had been made. Follow-up examination (October, 1944) revealed a small sacral fistula, the channel being the width of a match, with some discharge of secretion occasionally allowing the escape of feces, and full continence. No surgical intervention was, therefore, deemed necessary.

CASE 6.—The patient was a woman, aged 32 years, presenting a high, rectosigmoidal tumor. Dec. 15, 1943, colostomy was established in the transverse colon and on that occasion no metastases were noted in either the liver or colon. January, 1944, radical operation with primary pull-through was performed by the sacral approach. The bowel segment used for the pull-through developed gangrene, the wound had to be re-opened, and a sacral anus formed. An attempt to induce the sacral anus to prolapse by the pressure method outlined previously was successful. In April, 1944, it had already grown to a length that allowed the performance of a secondary pull-through operation. At that time the patient began to complain of abdominal symptoms and developed ascites. After withdrawal of fluid the metastases could be felt in the liver. The idea of a secondary pull-through operation was, therefore, abandoned. The fluid was several times drawn off and the patient died in a cachectic condition in August, 1944.

III. Secondary Pull-Through Operation After Radical Operation With Preservation of Sphincter Ani.—

CASE 1.—The patient was a woman, aged 63 years, with carcinoma 12 cm. above the anus, with circular stenosis. Oct. 30, 1940, colostomy of the transverse colon was constructed. Nov. 17, 1940, extended sacral operation was done. The sphincter was not touched, after 45 cm. of bowel had been mobilized. The tumor was above the pouch of Douglas. Together with the carcinoma, two polypi had to be removed. Owing to shortness of the colon, the operation was terminated by construction of a sacral anus. The sphincteric portion was ligated and buried. Recovery was interrupted by various complications (thrombophlebitis, pulmonary infarction) and not before July, 1941, could the patient be discharged. By encouraging the patient to make pressure exercises it was possible to induce the sacral anus to prolapse, so that soon sufficient length of bowel was available to be pulled through the sphincter which had been left intact (July 27, 1941). Healing was normal and no fistulas formed. Continence was fully restored. Toward the end of 1941, the patient developed severe polyarthritis with high temperature and myocardial insufficiency. She died toward the end of 1942 from acute cardiac disease. Clinically, neither local recurrence nor metastasizing could be detected. Since the patient died at home, no autopsy was made.

CASE 2.—The patient was a man, aged 40 years, a waiter, with a family history of carcinoma. Eight centimeters from the sphincter, there was a tumor of the posterior bowel wall. June 9, 1943, colostomy was performed on the transverse colon. June 30, 1943, radical operation (extended sacral method) was done. The sphincter could be spared. Owing to shortness of the bowel that could be mobilized, primary pull-through operation proved impossible and a sacral anus was established instead. The sphincteric segment was ligated and buried. The patient was encouraged to make pressure exercises and by October, 1944, a prolapse approximately 4 cm. long had protruded from the sacral anus. As there was no recurrence, secondary pull-through operation was performed with satisfactory result in January, 1945.

CASE 3.—The patient was a man of 36 years, who was admitted to the hospital in November, 1942. He had a stenosing tumor, at 15 cm. distance from the anus, for which rectoscopically as well as microscopically a diagnosis of carcinoma of the recto-sigmoid was made.

A preliminary colostomy was established in the transverse colon and on that occasion we satisfied ourselves that no metastasizing had so far occurred into the abdominal cavity. Radical operation (extended sacral method) followed on Dec. 11, 1942, during which 30 cm. of bowel were resected, together with its lymph nodes, and a sacral anus established after preservation of sphincters. The lymph nodes showed no microscopic evidence of malignancy. Healing was smooth.

Follow-up examination (November, 1944) showed a sacral hernia, the size of a man's fist, in a patient of an otherwise satisfactory state of general health, with normally functioning colostomy. The sphincteric segment which had been left in place on the occasion of the radical operation, had grown together at its upper circumference.

Jan. 4, 1945 operation was done on sacral hernia. A large segment of bowel, after dissecting off its adhesions to the Douglas pouch, was mobilized. An incision was made at a level between the base of the hernia and the upper part of the sphincter, and the "roof" of the latter reopened. The portion of bowel mobilized from the sacral wound was then pulled through the sphincter, the mucosa of which was left intact. The part used for the pull-through was in a normal state of nutrition and protruded by approximately 7 cm. from the natural anus. This protruding portion was later amputated. The sacral wound healed without fistulas (with some rehiscence of skin). The passage between the sphincter and the large intestine was free. On Jan. 14, 1945, the colostomy was closed by means of a Mikuliz clamp.

STATISTICS

In seven out of fifteen cases (after deduction of one fatal case) primary pull-through operation was done with satisfactory results that is, in 46.6 per cent) (Group I).

In Group II statistical calculations are difficult since in one of the cases the colostomy has not yet been closed, although there is every chance that the patient will have continence restored. Cases 1 and 5 regarding continence, can be con-

sidered as successful, while Case 6 was a complete failure. Owing to the diversity of the material, no accurate percentages can be given and it should be left to the reader to form his own opinion.

The secondary pull-through method was done, for external reasons (scarcity of beds available in the hospital), on only three patients, with good results in all.

In twelve out of sixteen cases, therefore, that is in 75 per cent, continence could be restored either by primary or secondary pull-through operation (excluding the one case in which the colostomy has yet to be closed).

SUMMARY

Guided by the idea that the restoration of continence is of prime importance, any radical operation which does not arrange for this possibility, although it would not imply loss of radicality, is regarded as imperfect. After referring to the methods suggested for this purpose in the Anglo-American, the French, and the German literature, the technique of the primary (Hochenegg) and the secondary (Weil) pull-through method is described, the latter by "artificial production" of prolapse (Mandl) from the sacral anus and operation on the sacral hernia. The pull-through procedure may be used equally as well after dorsal (sacral) or combined (abdominosacral) radical operation. So far the method devised by Hochenegg holds the greatest promise of success, regarding the restoration of continence after operation on the rectosigmoid, provided the indication is strictly adhered to. Nevertheless, it could be employed in only a certain number of cases of carcinoma (31.4 per cent of all cases) and was, in 46.6 per cent, followed by smooth healing by first intention. This percentage was further increased by adequate treatment of complications and by secondary pull-through operation, to 75 per cent.

A complete list of case records for the past five years is added.

It is pointed out that colostomy should precede the pull-through operation. Technical details are described. The method may be further developed.

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ACUTE COLONIC OBSTRUCTION SECONDARY TO CARCINOMA OF THE SIGMOID COLON WITH GANGRENE OF AN EXTENSIVE SEGMENT OF THE LARGE BOWEL

A CASE REPORT

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ACU TE mechanical obstruction of the colon due to carcinoma is not an uncommon occurrence. In the presence of a competent ileocecal valve, which allows the entrance of intestinal contents into the cecum but prevents the reverse flow of cecal contents into the ileum, extreme dilatation of the colon proximal to the site of obstruction and perforation of the cecum is the usual course of events, if prompt decompression of the obstructed bowel is not effected. An occurrence of gangrene of an unusually large segment of the colon coming on nine hours after the onset of symptoms of obstruction appears sufficiently noteworthy to merit mention in the surgical literature.

CASE REPORT

A 43 year-old white soldier was admitted to an Army General Hospital at 1 P.M., May 14, 1944. The evening before he had felt quite well, had worked for several hours, and had gone to bed around midnight. On awakening around 6 A.M., May 14, 1944, he experienced some mild lower abdominal cramps which became progressively more severe in the next hour, associated with abdominal gurgling noises. He had one small, apparently normal bowel movement shortly after the onset of the cramps, following which he passed no further gas or fecal matter by rectum. The cramps increased in severity throughout the morning and about three hours after the onset of his illness a progressive distention of the abdomen was noted along with a continuous pain between cramps. The patient felt nauseated but had no emesis.

About five weeks prior to this illness the patient had a similar, but milder, episode which lasted several hours and then spontaneously disappeared. His bowel habits and movements had been apparently normal. About ten months previously the patient had had a thorough gastrointestinal study in the United States, including colon x-ray and proctoscopic studies, following an attack of diarrhea. These studies apparently had yielded no positive results.

Physical examination shortly after admission to the hospital revealed an acutely ill, white man, 43 years of age. Temperature by rectum was 100° F., pulse rate 124, blood pressure 100/60. The abdomen was tensely distended and rigid throughout. There was marked tenderness in all quadrants of the abdomen. Because of the extreme distention and rigidity it was difficult to elicit rebound tenderness. On auscultation of the abdomen for a ten-minute period, no borborygmi could be heard. On digital examination of the rectum a tender boggy indefinite mass in the cul-de-sac could be felt. There was no blood noted in a small piece of fecal matter removed with the examining finger.

A scout x-ray film of the abdomen revealed a markedly dilated loop of colon occupying the area of the hepatic flexure (Fig. 1). The splenic flexure was moderately dilated with gas extending down into the area of the sigmoid colon. Study of the patient's urine revealed no abnormalities other than 15 to 20 white and red blood cells per high-powered field and fairly numerous granular casts. The white blood count was 9,100 of which 85 per cent were polymorphonuclear cells, 14 per cent lymphocytes, and 1 per cent monocytes.



Fig 1—Scout x-ray film of the abdomen showing extreme dilatation of the right colon

A diagnosis of possible volvulus of the sigmoid colon or acute mechanical obstruction of the sigmoid colon, possibly due to carcinoma, was made. After receiving 500 c.c. of plasma the patient was taken to the operating room.

The operation was started at 3 P.M. under ether oxygen anesthesia through a lower abdominal left rectus incision. When the peritoneal cavity was entered, about 1,000 c.c. of brown, foul-smelling peritoneal fluid was encountered. (A culture of this fluid subsequently revealed no growth of any organisms after forty-eight hours.) The colon was found to be enormously dilated and gangrenous. Because of the extreme distention it was impossible to mobilize the bowel sufficiently at this stage of the operation to ascertain the extent of the involvement. To gain exposure, the upper end of the left rectus incision was extended laterally and to the right, above the umbilicus, to beyond the lateral border of the right rectus muscle. In this manner satisfactory exposure was obtained. The entire colon from ileocecal valve to the midportion of the descending colon, where the process faded off to healthy looking bowel, was found to be gangrenous. There were several serosal rents over the cecum and ascending colon but no perforation had occurred. The terminal ileum was of normal size and appearance. In the sigmoid colon, about 15 cm. above the peritoneal reflection, was a small, annular,

constricting, napkin ring-shaped tumor, about 3 to 4 cm. in diameter. Because of the gangrene of the colon no procedure other than colectomy was feasible. This was started by transecting the ileum about 4 cm. proximal to the ileocecal junction. Colectomy (Fig. 2) was then undertaken beginning at the cecum and progressing down the colon to about 5 cm. below the carcinoma. No spillage occurred during this procedure. No enlarged lymph glands or metastases of the carcinoma to other organs were noted. The stomata of the distal portion of the sigmoid colon, a segment about 10 cm. above the peritoneal reflection, and the terminal ileum were brought out side by side through the left rectus part of the incision. The remainder of the operative wound was closed in layers without drainage. During the operative procedure, which lasted three hours, the patient received 1,000 c.c. of whole blood, 750 c.c. of plasma, and 1,000 c.c. of normal saline. At the completion of the operation the patient's condition was satisfactory, the blood pressure was 118/70, and the pulse rate was 140.

Postoperatively the patient had continuous suction applied to an indwelling nasal gastric tube and to a catheter in the ileostomy stoma for three days. He received penicillin at three-hour intervals intramuscularly, 240,000 Oxford units in all being given daily for three days, then 120,000 units for two days when it was discontinued. Aside from a moderate wound infection about the ileostomy stoma, the patient's postoperative course was satisfactory. The highest postoperative temperature was 101.8° F. by rectum on the second and third postoperative days, after which it dropped to normal.



Fig. 2.—Colon at the time of operation with the cecum and the appendix from which a forceps is hanging held uppermost. The color change of the black gangrenous colon can be compared to the color of a normal loop of ileum seen below in the operative wound.

Pathologic Report (Fig. 3).—The specimen consisted of a segment of colon (sigmoid through cecum) 137 cm. long and attached appendix and 4 cm. segment of ileum. At the cecum it measured 14 cm. in diameter and toward the distal end 6 cm. in diameter. At a point 5 cm. above the distal plane of excision there was an annular, constricting, ulcerated, indurated tumor 4 cm. long. The lumen was reduced to about 1 cm. in diameter. On section the entire wall of the bowel was indurated and the overlying adipose tissue was adherent to a slightly granular serosal surface posteriorly. There were no nodes in the scant amount of attached mesentery. From a point 8 cm. above the tumor to the ileocecal valve, the entire wall of the bowel was black and softened, and became progressively thinner as the cecum was approached. There were several splits in the serosa over the cecum. The lumen contained gas and about three liters of watery fecal material.

Microscopic.—A section from the tumor showed the entire wall of the colon to be irregularly infiltrated with poorly differentiated glands and small nests of epithelial cells. The transverse colon showed necrosis, most extensive in the mucosa, extensive submucosal edema, and diffuse polymorphonuclear infiltration through the submucosa, serosa, and patchy in the muscularis. The cecum showed necrosis involving all layers of its wall. There were but a few isolated leucocytes.

Diagnosis.—Adenocarcinoma of the sigmoid colon and gangrene of the colon.

July 7, 1944, under combined intravenous pentothal and spinal metycaïne anesthesia, the patient was reoperated upon. The colostomy and ileostomy stomata were dissected free and an end-to-end intraperitoneal ileosigmoidostomy was performed. On exploration at this time no evidence of recurrence of the carcinoma was noted. At the time this paper was submitted for publication, one month after the last operation, the patient is entirely well, and has about three soft, well-controlled bowel movements daily.



Fig. 3.—Resected specimen

Wangensteen* has pointed out that, in the distention of complete large bowel obstructions, the intraluminary tension exerted on the cecal wall, because of its greater diameter, is greater per square centimeter than in any other segment of the colon. For this reason perforation of the cecum usually occurs before the intraluminary pressure becomes sufficiently high to compromise the viability of the remainder of the colon. This case is unique in that gangrene of the colon, from cecum to descending colon, occurred in the relatively short period of nine hours without resulting in perforation at the usual cecal site.

*Wangensteen, O. H. *The Therapeutic Problem in Bowel Obstructions*, ed. 2, Springfield, Ill., 1942, Charles C. Thomas, Publisher.

THE USE OF A TRANSVERSE ABDOMINAL INCISION IN, AND COMMENTS ON, THE SURGICAL TREATMENT OF INFANTILE PYLORIC STENOSIS

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THE recent comprehensive review by Szilagyi and McGraw¹ of all phases of infantile pyloric stenosis makes an extended discussion of most aspects of the subject unnecessary at this time. These authors' historical review of surgical therapy, however, contains no mention of a type of abdominal incision which I have used for some time with such satisfactory results that I think it worth describing.

DESCRIPTION OF PROCEDURE

The steps of the operation are as follows:

1. A high transverse incision is made on the right side between the umbilicus and the ensiform cartilage, through the skin and subcutaneous tissues. A second transverse incision is made in the anterior sheath of the right rectus abdominis muscle. The sheath of this muscle is dissected free from the muscle fibers and retracted upward and downward (Fig. 1). The rectus abdominis muscle is dissected from the posterior sheath and retracted mesially. A third transverse incision is made in the posterior sheath of the muscle and the peritoneum (Fig. 2).

When the dilated stomach presents itself in the wound, as it does immediately upon the completion of the peritoneal incision, the prepyloric portion can readily be grasped and the hypertrophied pylorus delivered into the wound, where it is held between the left index finger and the thumb.

2. A modified Frédet-Weber-Rammstedt operation is carried out. Two longitudinal incisions are made in the hypertrophied pylorus through the serosal and muscular coats and the edges of both incisions are spread apart with Mayo dissecting scissors, so that the mucosa bulges into them. The pylorus is then released and is permitted to drop back into the peritoneal cavity.

3. After the intra-abdominal procedure has been completed, the posterior sheath of the right rectus abdominis muscle is closed with interrupted cotton-sutures (Fig. 3). The retracted muscle is released and is permitted to return to its normal position. The incisions in the anterior sheath of the rectus muscle and in the skin are also closed with interrupted cotton sutures.

A compression dressing of fluffed gauze or cotton waste is placed over the wound and strips of elastic adhesive plaster are applied diagonally. Slight pressure is thus achieved, while at the same time there is no constriction that would interfere with respiratory movements of the chest and upper abdomen.

ANALGESIA

Local analgesia, which is often stated to be unsuitable for operations in very young children, will prove entirely practical if, when the child is placed on the table or shortly before, he is given a sugar teat made of a piece of muslin or of several thicknesses of gauze saturated with a solution of equal parts of whiskey and water, and is permitted to suck it throughout the operation.

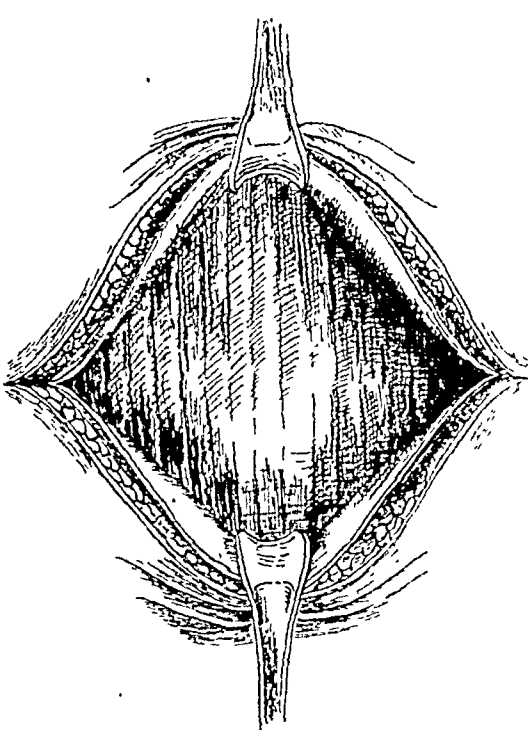


Fig. 1.

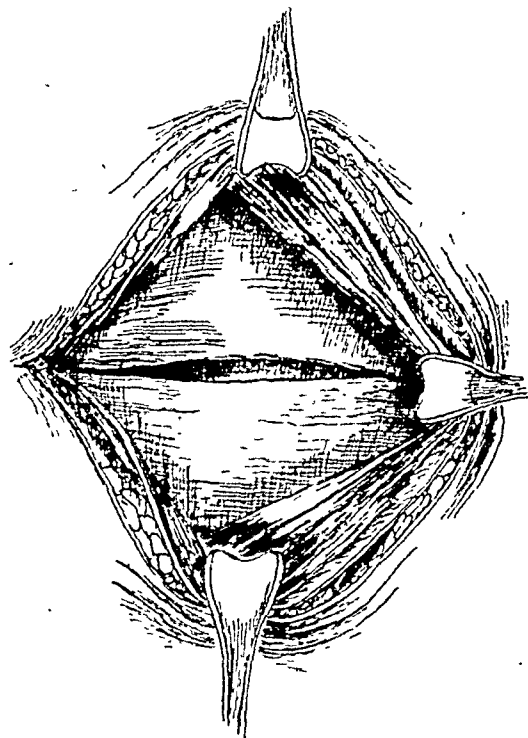


Fig. 2.

Fig. 1.—The right rectus abdominis muscle has been exposed by a transverse incision through the skin, subcutaneous fatty connective tissue, and anterior muscle sheath. The anterior sheath has been dissected from the right rectus muscle and is retracted upward and downward.

Fig. 2.—The right rectus abdominis muscle has been retracted mesially and a transverse incision has been made through the posterior sheath and the peritoneum.

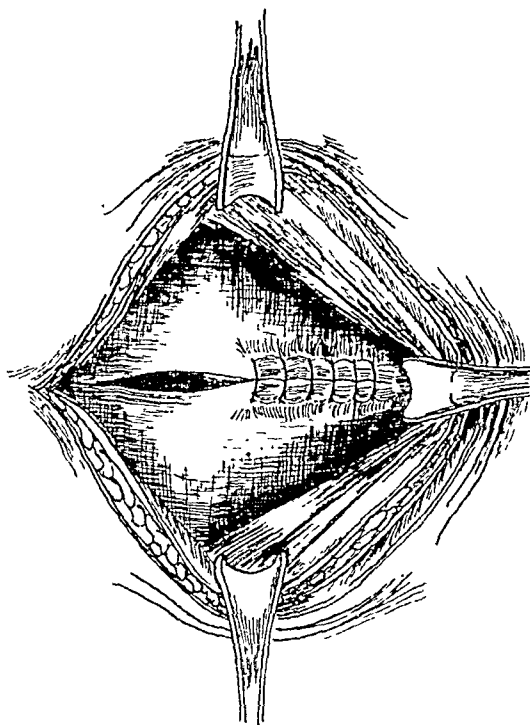


Fig. 3.—Closure of the wound has been begun by the use of interrupted sutures of quilting cotton in the posterior sheath of the right rectus abdominis muscle.

The abdominal wall and the operative field are blocked by the injection of a solution of 0.5 per cent novocain, very little of which is used in the fascia, muscle, and peritoneum. The perimeter of the injected area, however, should be sufficiently large to permit the incision to be made and the wound edges to be retracted without disturbing the child. If the initial injection is made correctly, the entire operation can be completed without a second injection.

DISCUSSION

Unquestionably, certain mild cases of pyloric stenosis can be treated satisfactorily by nonsurgical measures. On the other hand, if surgery were done promptly in all cases, the general results would undoubtedly be materially improved. The surgical results, particularly in America, have improved consistently over the years, but the death rate in this disease is still too high, chiefly because patients are held on dietary and medical treatment for long periods of time, the average physician or pediatrician being reluctant to recommend operation for infants. In short, as many writers have pointed out, a large part of the surgical mortality in pyloric stenosis is really nonsurgical in origin.

Part of the mortality in infantile pyloric stenosis, however, is also due to inadequate preoperative and postoperative care. To delay surgery for preoperative preparation is essential in the usual case and a wise precaution in almost every case, for the nutritional status of these infants is seldom optimum. A poor surgical risk can usually be transformed into a better one, or even into a good one, by such measures as the subcutaneous injection of physiologic salt solution, the intravenous use of physiologic salt solution combined with dextrose or with Hartmann's modification of Ringer's solution, and repeated small blood transfusions. If there is difficulty in administering these solutions by way of an arm or a neck vein, tibial puncture can be resorted to; the bony tibial cortex is not hard at this period of life, and usually entrance can be made with a very light rotating motion of the needle, although aseptic precautions must be taken. Injection by way of the longitudinal sinus is another possibility.

Preoperative medication, including all types of sedation, is unnecessary and may be actually injurious. The same holds true of gastric lavage and intranasal gastric intubation. Both of these measures tend to increase the incidence of respiratory complications, particularly aspiration pneumonia, and are never necessary if oral feeding is discontinued for twelve hours before operation.

Oral feeding is not resumed until twelve hours after operation, and the first feedings are at long intervals. The intervals are gradually shortened as the stomach adapts itself to the handling of food. If the infant has been breast fed, the maternal milk should be pumped out and used. Otherwise, small feedings of a thin formula, or even of water alone, are best until a regular feeding schedule with an adequate formula can safely be instituted.

Vomiting is not uncommon for one or two days after operation. Occasionally it is frequent and lasts for several days, for which there are two possible explanations: (1) The enlarged, irritable stomach is accustomed to emptying itself in this manner. (2) Following pyloromyotomy the mucous membrane and muscularis become swollen and edematous, and it may be some days before the tissues return to their normal state and the stomach can freely empty into the duodenum through the pyloric ring.

In all patients, and particularly those in whom vomiting occurs, the use of parenteral solutions, including blood, is as wise after operation as it is necessary before. My own experience is that when these measures are employed the

operation is attended with little shock, convalescence is smooth, peritoneal infection and wound infection seldom occur, and disruption of the wound is almost never observed.

As far as I know, no abdominal incision precisely similar to the one I have described, for approaching the hypertrophied pylorus, has previously been recorded. Davis,² in 1944, proposed a somewhat similar one which, however, included a longitudinal incision of the fibers of the right rectus abdominis muscle.

I believe that the abdominal incision which I have proposed is superior to this incision, as well as to the other incisions ordinarily used (high right rectus, high midline, right subcostal) for the following reasons:

1. Since the approach to the pylorus is by way of the fascia, no muscles are injured.

2. The incision is directly over the prepyloric region of the stomach, which makes it possible to deliver the hypertrophied pylorus into the wound without difficult and traumatic manipulations.

3. Closure is simple, and when it is accomplished there is no tension on the suture lines in the anterior and posterior rectus sheaths, between which the right rectus abdominis muscle lies as a buffer. Dehiscence of the wound is therefore highly unlikely, even if vomiting is persistent.

4. The infant can be placed on the side, if desired, immediately after operation, and in the prone position within a few hours.

5. The minimum trauma produced by the incision favors prompt healing of the wound.

I have deliberately termed the basic operation for infantile pyloric stenosis the Frédet-Weber-Rammstedt operation, although it is usually known merely as the Rammstedt operation, or at most as the Frédet-Rammstedt operation, Weber's contribution being entirely ignored. A note on the evolution of the procedure therefore seems in order.

Pyloroplasty, which was the preferred surgical treatment for infantile pyloric stenosis in the first years of this century, clearly did not solve the problem. Frédet,³ who performed his first operation Oct. 12, 1907, obviated its two most objectionable features (opening of the infected gastric cavity, which invited peritonitis, and sectioning of the vascular mucosa, which introduced the risk of hemorrhage) by carrying the longitudinal incision only to the mucosa and by not opening the stomach. He sutured the muscularis transversely, but noted that the tension on the muscular layers of the pylorus was so excessive that a diamond-shaped area of mucosa had to be left uncovered.

In Germany, Weber,⁴ without knowledge of Frédet's work, used the same technique, on Dec. 3, 1908. Unlike Frédet, who used the procedure only once, he employed it in three patients, in one of whom death occurred from hemorrhage. The operation was severely criticized, and no one else performed it until September, 1911, when Rammstedt⁵ performed it, using Weber's technique, without knowledge of Frédet's work.

Rammstedt's patient vomited persistently for several days, after which vomiting abruptly ceased and recovery was smooth. The abrupt turn for the better, he speculated, could be explained only by the giving way of the sutures, which permitted the wound to right its direction, the edges to separate, and the mucosa to protrude. Three months later, in January, 1912, Rammstedt operated for pyloric stenosis by the same technique, but omitting the sutures, and thus the modern operation was born. Incidentally, after Rammstedt's work was popularized, Frédet resumed the operation; in the thirteen years which

had intervened since he first performed it, he had treated infantile pyloric stenosis by gastroenterostomy.

SUMMARY

A transverse abdominal incision for use in the approach to the hypertrophied pylorus in infantile pyloric stenosis is described, and has not, as far as can be determined, been previously described. Certain phases of preoperative and postoperative care which add materially to the safety of the operation are also discussed.

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GANGRENOUS CYSTITIS

ETIOLOGIC CLASSIFICATION AND TREATMENT

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STIRLING and Hopkins,‡ in 1934, reviewed the literature concerning gangrene of the bladder. They found reports of 207 cases, to which they added reports of two cases of their own. Most urologists and pathologists agree that this frequently fatal condition is much more common than the case reports would indicate.

Many etiologic factors have been mentioned in connection with the reports of cases that have appeared in the literature. On the basis of these factors we evolved the classification shown in Table I. A variety of names for the pathologic changes also have appeared in the literature. These include croupous cystitis, diphtheritic cystitis, dissecting gangrenous cystitis, exfoliative cystitis, gangrenous cystitis, membranous cystitis, and pseudomembranous cystitis.

Apparently gangrenous cystitis has been found most frequently in women. In the majority of cases the condition has been thought to be a complication of labor. It is attended by a high mortality. Stirling and Hopkins found that of the 200 cases in which the outcome was known, death had occurred in 120 and recovery in only 80. More recently cases of gangrenous cystitis associated with excessive coagulation after transurethral prostatic operations have been added to the literature.

The clinical picture is most frequently one of severe infection of the urinary tract. The accompanying constitutional reaction is extreme if the process has extended to the kidneys. Boardlike rigidity of the abdomen is evident in those cases in which the peritoneum is involved. Fetid ammoniacal urine containing

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‡Stirling, W. C., and Hopkins, G. A.: Gangrene of the Bladder: Review of Two Hundred Seven Cases; Report of Two Personal Cases, *J. Urol.* 31: 517-525, 1934.

TABLE I. ETIOLOGY OF GANGRENOUS CYSTITIS*

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- I. Direct causes: Production of cellular death
 - A. Chemical irritation
 1. After instillation of solutions that are too caustic or too acid, intentionally for the treatment of cystitis or accidentally for the induction of abortion
 - B. Physical irritation
 1. Secondary to excessive thermal, roentgen, or radium exposures
 - C. Infections
 1. Protracted chronic cystitis (frequently associated with vesical overdistention)
 2. Associated with general systemic infections (typhoid, diphtheria, bacillary dysentery, and so forth)
 - II. Indirect causes: Interference with blood supply and nutrition of bladder
 - A. Mechanical closure by pressure, ligature, or overstretching of tissues
 1. Chronic urinary retention with overdistention of the bladder from any cause (impacted vesical or urethral calculi, urethral stricture, ruptured urethra, prostatic hypertrophy, general surgical procedures, and so forth)
 2. Extravesical pressure as from a gravid, impacted uterus or incarcerated uterine myoma, usually associated with vesical overdistention
 3. Circulatory obstruction secondary to a surgical procedure performed on, or adjacent to, the bladder
 - B. Injury or disease of the blood vessels
 1. Transurethral operative procedures on the prostate gland
 2. Difficult and prolonged labor
 3. Secondary to severe mechanical trauma of pelvis from without
 - C. Thrombosis and embolism
 1. Secondary to causes of injury or disease of the blood vessels previously listed
 2. After roentgen or radium irradiations
 3. Metastatic bacterial emboli
 - D. Disturbance due to nerve influences
 1. Cord bladders associated with overdistention and urinary infection.
-

*General conditions, such as age, diabetes, nephritis, acute disease (typhoid fever), and debility, which are believed to weaken the tissue resistance, promote these causes. The activity of the process can be facilitated further by secondary introduction of bacteria.

much pus, blood, albumin, detritus, and bits of membrane containing vesical tissue is practically diagnostic.

Treatment consists of early and adequate drainage. In men, early suprapubic drainage with removal of the necrotic membrane is advocated by all authors who have discussed treatment for this condition. After recovery, treatment of any lesion which causes interference with the vesical blood supply should be instituted. Occasionally spontaneous cure may take place in women since the urethra is sufficiently ample to permit the passage of necrotic material. However, as illustrated by the accompanying case report, spontaneous extrusion of the necrotic material may result in apparently permanent urinary incontinence.

This case is reported for the following reasons: (1) It represents a case of spontaneous cure; (2) the extruded material is a complete cast of the bladder (Fig. 1); (3) A careful follow-up study reveals that perhaps women as well as men should receive early suprapubic drainage with removal of the necrotic material in the hope of avoiding damage to the external urinary sphincter.

REPORT OF CASE

An unmarried white woman, aged 64 years, was admitted to the Mayo Clinic in August, 1942. She was profoundly dyspneic and gave a history of having suffered from bronchial asthma for the last fifteen years. The asthmatic attacks always had been worse in the winter, but this year the respiratory discomfort had persisted throughout the summer months. She had been hospitalized and a letter from her local physician revealed that she had not responded to the usual forms of treatment. Five other members of her family also suffered from bronchial asthma.

Physical examination revealed a tense and anxious woman who appeared to be suffering from severe respiratory embarrassment. She was well developed and well nourished.

The chest was filled with musical râles but otherwise physical examination revealed no abnormalities. Roentgenogram of the chest revealed bilateral emphysema.

The patient promptly was hospitalized and treated with an oxygen-helium mixture and a variety of antiasthmatic drugs. Despite all therapeutic measures she gradually became comatose and on the second day the outlook was considered to be grave. All laboratory tests were normal except that the concentration of urea was 96 mg. and of sugar was 146 mg. per 100 c.c. of blood, respectively. The urine was free from sugar and contained many casts and no pus cells.



Fig. 1.—Spontaneously extruded cast of bladder and urethra.

The patient could not be aroused on the fourth day in the hospital, but she was moving all extremities and was breathing easier. A neurologic survey including examination of the cerebrospinal fluid and ocular fundi revealed nothing abnormal. Urinary retention developed on the seventh day and catheterization was required until the seventeenth day. During this interval oliguria was present. The urine, which had been free from blood, pus, and organisms, became grossly hemorrhagic on the eleventh day. By this time the patient was completely conscious and was breathing normally. The urinary output returned to normal and the urine became clear on the thirteenth day. By the twentieth day the patient felt so well that she insisted on returning home and was referred to the care of her local physician. At the time of dismissal, she had some urinary frequency. The concentration of blood urea was 58 mg. and the amount of blood sugar was normal. The urine contained many erythrocytes and an occasional pus cell.

The patient returned to the clinic approximately four weeks after dismissal from the hospital and reported that five days previously she had passed a mass of tissue (Fig. 1) through the urethra after three days of intense discomfort in the bladder. Since that experience she had had no control over the excretion of urine, which had continued to be bloody. The expelled mass of tissue, which the patient presented in a bottle, was reported by the pathologists to be "partially necrotic and inflammatory bladder tissue." Careful physical examination was negative. The results of examination of the urine were negative except for many erythrocytes. The concentrations of both the blood sugar and the blood urea were normal. An excretory urogram revealed no abnormalities. Cystoscopic examination under anesthesia induced by intravenous pentothal sodium revealed marked diffuse cystitis with considerable residual old blood remaining in the bladder. All remaining necrotic material was removed from the bladder and a catheter was left in place. Continuous irrigation of the bladder with a solution of sulfanilamide was instituted for several days. When the patient was dismissed on the third day she felt well but still had some urinary incontinence.

In May, 1944, the patient returned for re-examination, at our request. She was evidently in good health and was free from asthma. Although she periodically voided small amounts of urine, she was generally incontinent. The concentration of blood urea was 76 mg. The urine contained many pus cells and an occasional erythrocyte. Culture of the urine revealed *Escherichia coli*. An excretory urogram was unsatisfactory, but it did reveal little or no evidence of function in the right kidney. Cystoscopic examination performed under anesthesia induced by intravenous pentothal sodium demonstrated markedly reduced vesical capacity, grossly normal vesical mucosa, an apparently normal left ureteral orifice, and a markedly shortened urethra. The right ureteral orifice could not be located. The patient was referred to her local physician for irrigations of the bladder and periodic courses of sulfonamide therapy. The abrupt and lasting cessation of bronchial asthma puzzled the internists who examined this patient.

COMMENT

In the past the treatment prescribed for gangrenous cystitis has been dependent on the sex of the patient. Prompt suprapubic drainage with removal of necrotic material was recommended for men. Spontaneous extrusion of necrotic material or removal through the cystoscope was advised for women.

A case of gangrenous cystitis in which the patient had expelled a cast of the bladder through the urethra has been presented. Since this experience resulted in apparently permanent urinary incontinence, early suprapubic drainage for both sexes is recommended.

HUMAN FIBRIN FOAM WITH THROMBIN AS A HEMOSTATIC AGENT IN GENERAL SURGERY

EXPERIMENTAL STUDIES AND CLINICAL USE

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COMPLETE hemostasis with minimal tissue injury is essential in all branches of surgery. This objective may be attained in many operative procedures by ligature, endothermy, and other methods, but there remain certain situations in which the techniques now available have their shortcomings. It appears, therefore, that in special situations new hemostatic agents may be of value.

The fractionation of human blood plasma in the Department of Physical Chemistry of the Harvard Medical School¹ has provided a method for the preparation of human fibrinogen and thrombin on a large scale.² From these proteins, it is possible to prepare a spongy material, fibrin foam,³ which becomes an effective absorbable hemostatic agent when soaked in human thrombin solution.

Experimental and clinical investigations from the standpoint of the neurosurgeon⁴⁻⁷ have shown that fibrin foam with thrombin can be used to control bleeding from oozing surfaces, from the dural sinuses, and from large cerebral veins. Furthermore, when it is left in place, it excites a negligible tissue reaction. Studies were at first confined to the central nervous system. The situations in which fibrin foam with thrombin finds its greatest usefulness are most frequent there; furthermore, small amounts of oozing within the closed cranial cavity may be fatal, whereas the loss of the same quantity of blood in other tissues creates only a minor complication of wound healing. On the dura and within the brain substance, previous studies⁴⁻⁷ have shown that the fibrin foam rapidly becomes more compact and is absorbed with only slight cellular infiltration within a month or less. The final fibrous tissue reaction is so slight that it usually cannot be identified in tissue sections. The final reaction to a large quantity of fibrin foam with thrombin is less than that to a single black silk suture.

There are certain operative procedures in general surgery during which the control of oozing from vessels not suitable for ligature may require a great deal of time or be difficult to effect with conventional techniques. These include the cut surfaces of the liver, kidney, and lung, as well as the abdominal wall, muscles, and peritoneum in certain patients, especially those with jaundice, hemophilia, and bleeding tendencies due to other causes. Fibrin foam with thrombin has been used under all these conditions and has been found speedily effective in controlling capillary and venous bleeding. While many studies of the tissue reactions to fibrin foam with thrombin in the central nervous system

This work has been carried out under contract recommended by the Committee on Medical Research between the Office of Scientific Research and Development and Harvard University.

This paper is No. 33 in the "Studies on Plasma Proteins" of the Harvard Medical School, on products developed by the Department of Physical Chemistry from blood collected by the American Red Cross.

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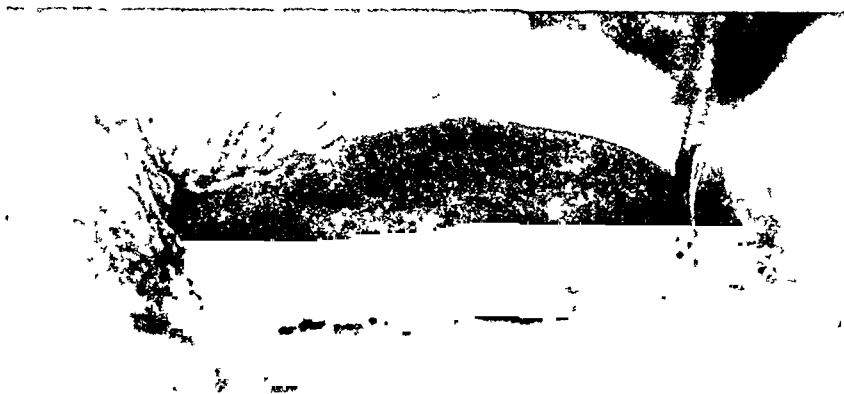
have been carried out, we have regarded investigations in other organs and comparison with various absorbable hemostatic agents as essential before recommending clinical use of fibrin foam with thrombin in general surgery. It is the purpose of this report to describe these experiments and to discuss experiences with the clinical use of fibrin foam with thrombin in general surgery.

EXPERIMENTAL STUDIES

Fibrin Foam With Thrombin in the Liver

Circumstances requiring an absorbable hemostatic agent in general surgery are frequently encountered in dealing with hepatic lacerations, tumors, or other lesions for which the liver parenchyma is incised. Experiments to determine the

A.



B.

Fig. 1.—Procedure 1. Experimental laceration of the liver, showing: A, free bleeding before the application of fibrin foam with thrombin, B, hemostasis resulting from the use of fibrin foam with thrombin.

tissue reactions to human fibrin foam with thrombin were therefore carried out in animals and these reactions compared with those excited by various other hemostatic agents. All experiments were carried out under nembutal anesthesia unless otherwise stated. Sections for histologic study were stained with phloxine and methylene blue after fixation in acetic Zenker's solution.

Procedure 1.—The left lobe of the liver was delivered into a laparotomy wound, so that about 3 cm. of its surface was exposed. A scalpel was plunged

into the liver to a depth of 2 cm. and drawn through the liver substance for approximately 4 cm. The laceration of the liver was then packed with fibrin foam with thrombin. One or two mattress sutures of black silk were placed in the liver capsule to close the laceration. Effective hemostasis was secured (Fig. 1). This procedure was carried out in five monkeys, which were autopsied at the following intervals after operation: 30 minutes, 4 hours, 21, 70, and 74 days.

Pathologic studies: Sections of unimplanted fibrin foam, sectioned for comparison (Fig. 2), were composed of meshes of fibrin which stained deep blue with the phloxine-methylene blue technique. These represented cross sections of the honeycomb-like spaces in the fibrin foam. In the specimen obtained 30 minutes after operation (Fig. 3) the fibers of the fibrin foam were little changed from those of the control specimen. Some of the spaces were filled with well-formed blood clot, indicating that blood oozing into the center of the mass

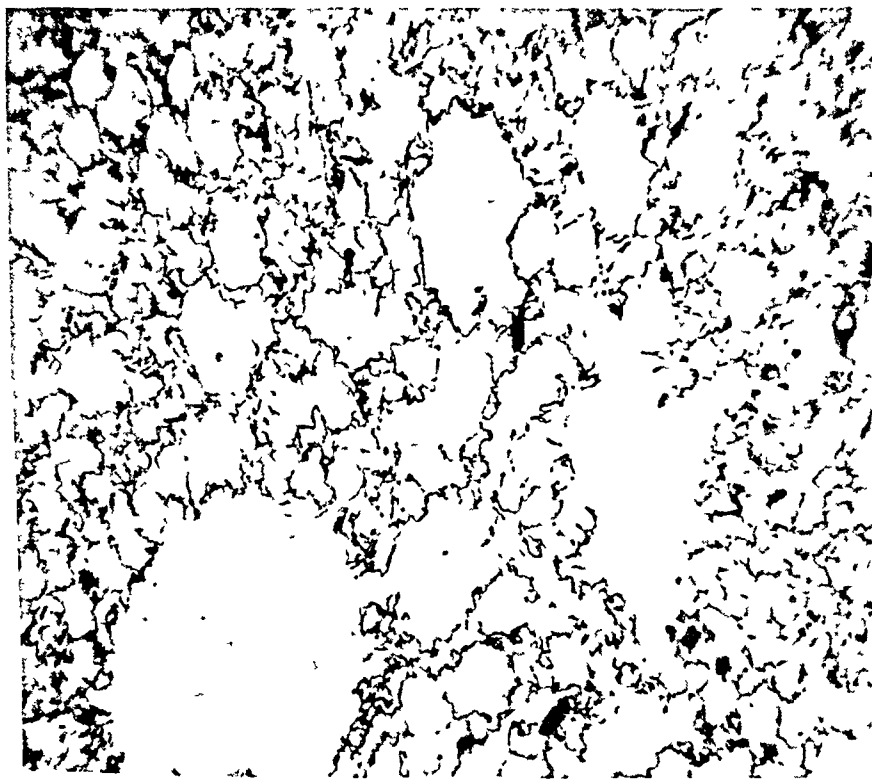


Fig. 2—Histologic appearance of fibrin foam before implantation (Phloxine methylene blue stain, $\times 54$.)

of fibrin foam was promptly coagulated. There were no leucocytes within the substance of the material but a few groups of leucocytes were present at the line of incision. These were probably due to the trauma of the operation rather than to the presence of the fibrin foam, since they were found only along the line of incision. Adjacent liver cords were somewhat compressed but were otherwise normal.

At 4 hours, the fibrin foam had decreased markedly in volume. The meshes were much smaller (Fig. 4) and the fibers in most places took the phloxine stain, although some of them at the center still stained with methylene blue. The blood clot in the interstices was still present and a very few polymorphonuclear leucocytes had made their appearance within the meshes of the fibrin foam. In some areas, both at the center and adjacent to the liver tissues, considerable

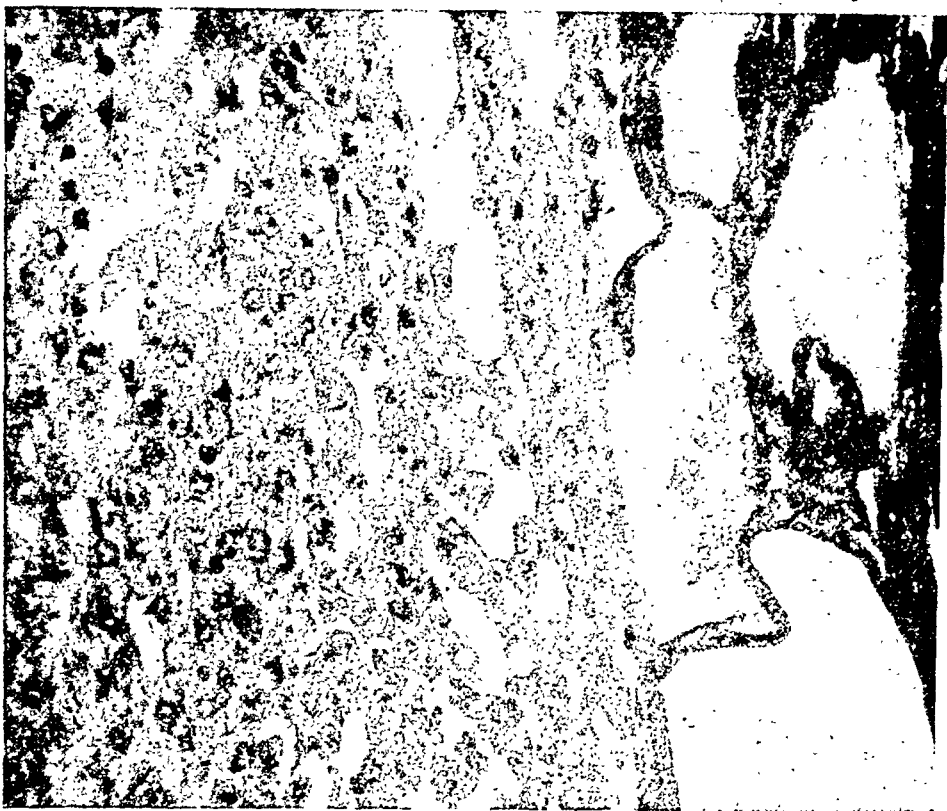


Fig. 3.—Procedure 1. The monkey had been sacrificed 30 minutes after the application of fibrin foam with thrombin to an experimental laceration of the liver. The meshes of the fibrin foam are beginning to become smaller; they contain some red blood cells. The adjacent cells of the liver parenchyma are pyknotic and somewhat fragmented as the result of the operative procedure. At this stage there is no inflammatory cellular infiltration in response to the fibrin foam with thrombin. (Phloxine methylene blue stain, $\times 300$.)



Fig. 4.—Procedure 1. The monkey had been sacrificed 4 hours after the application of fibrin foam with thrombin to an experimental laceration of the liver. The meshes of the fibrin foam are much smaller than at 30 minutes after application. They contain clotted blood. Note the absence of inflammatory cellular reaction to the fibrin foam at this stage. (Phloxine methylene blue stain, $\times 300$.)

liquefaction of the fibrin foam had occurred, the spaces being occupied in sections by a phloxine-staining precipitate. This process was not accompanied by leucocytic infiltration.

At 21 days after operation, a small mass of fibrin foam was still demonstrable (Fig. 5). This was compact and showed little evidence of the original honeycomb structure. The fibers were swollen and took the phloxine stain. About the periphery, there was a small amount of fibrous tissue proliferation with slight infiltration by mononuclear cells and lymphocytes. A few giant cells were present.

In the animals sacrificed at 70 and 74 days no traces of fibrin foam were found. The wounds had healed with the formation of a cicatrix which did not seem larger or different in character from scars in which no fibrin foam had been used (Fig. 6). Conspicuous tissue reaction with giant-cell formation was found about the black silk sutures.

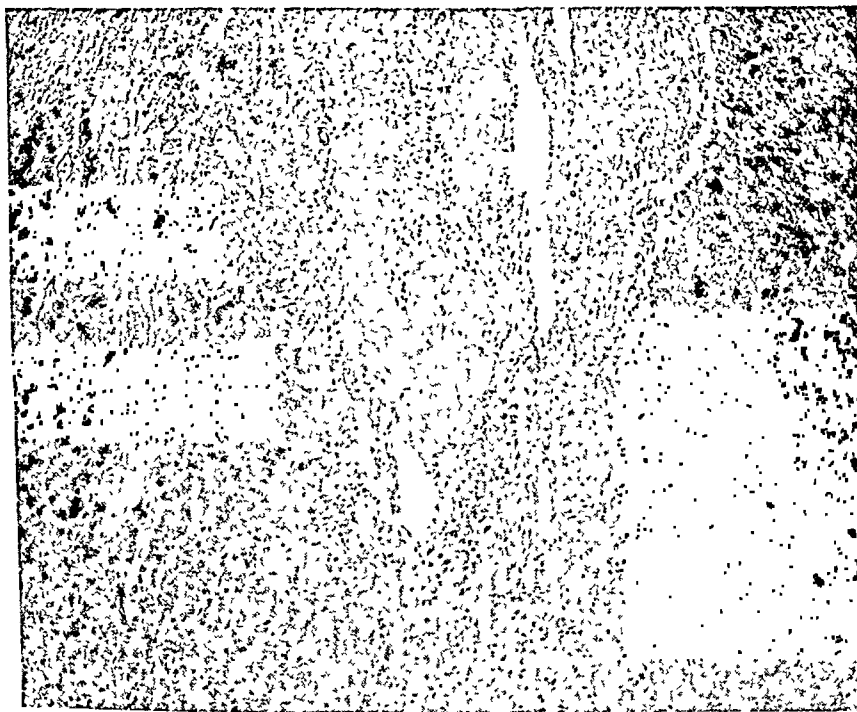


Fig. 5.—Procedure 1. The monkey had been sacrificed 21 days after the application of fibrin foam with thrombin to an experimental laceration of the liver. At the right of the photomicrograph, there is a small compact mass of fibrin foam not yet absorbed. Scar tissue is forming at the center. (Phloxine methylene blue stain, $\times 110$.)

Result: Fibrin foam with thrombin satisfactorily controlled bleeding from experimental liver lacerations in five monkeys. Tissue reaction was minimal, the hemostatic material being almost completely absorbed in 21 days and entirely so at 70 days. The amount and character of the scar tissue was not demonstrably altered by the use of fibrin foam with thrombin.

Procedure 2.—A stab wound was made in the liver and a cube of fibrin foam 1 by 1 by 1 cm., soaked in human thrombin solution, was inserted 1 cm. below the surface of the liver. The wound was closed with one black silk suture to serve as a marker. A cube of soluble cellulose of the same size and also soaked in human thrombin solution was inserted at a similar depth below the capsule of a different portion of the liver. This procedure was carried out in five monkeys, which were sacrificed at the following intervals after operation: 11 and 16 days, 8½ and 12 weeks.

Pathologic studies: At 11 days, the fibrin foam had been absorbed save for a few fragments. The fibers were clumped in small groups and the original honeycomb structure had disappeared. At the centers of the fibers of residual fibrin foam, the material was deep blue, while it was stained with phloxine where it came in contact with the tissue. These remnants were surrounded by moderate numbers of polymorphonuclear leucocytes, mononuclear cells, and a few lymphocytes. Giant cells were found about some of the smallest fragments. The amount of soluble cellulose remaining was approximately the same as that of fibrin foam.

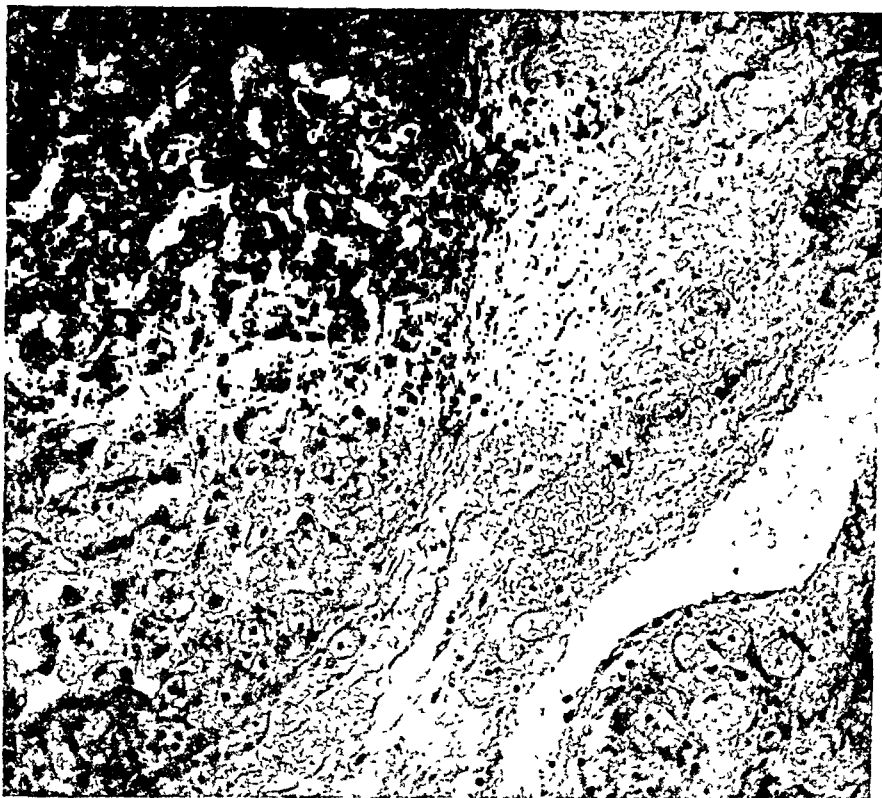


Fig. 6.—Procedure 1. The monkey had been sacrificed 70 days after the application of fibrin foam with thrombin to an experimental laceration of the liver. The fibrin foam has been completely absorbed and there are no characteristics of the scar which can be correlated with the use of this hemostatic agent. (Phloxine methylene blue stain, $\times 200$.)

In the specimen obtained at 16 days, the amount of fibrin foam remaining was similar to that found at 11 days. Fibrillar structure was no longer apparent, the fragments being homogeneous and staining entirely with phloxine. Giant cells were more numerous while polymorphonuclear leucocytes had almost disappeared and had been replaced by mononuclear cells. Proliferation of connective tissue was present about the fragments of fibrin foam, blending with the rest of the scar tissue. Only minute fragments of the soluble cellulose were found. The region in which it had been implanted was occupied by a mass of giant cells, often containing bits of the soluble cellulose, together with moderate numbers of mononuclear cells and a few polymorphonuclear leucocytes. There was proliferation of connective tissue in the region. How much of this was due to the soluble cellulose and how much to the healing of the incision per se could not be determined.

No traces of fibrin foam or of soluble cellulose were found in the animals sacrificed 5, 8½, or 12 weeks after operation. In all instances, the incisions were well healed by compact cicatrices containing no elements which could be related definitely to implantation of either type of hemostatic material.

Result: When embedded in the liver of monkeys, fibrin foam with thrombin and soluble cellulose with thrombin were absorbed at the same rate. Both caused tissue reaction of about the same amount and character.

Procedure 3.—Procedure 2 was repeated with the variation that sulfadiazine was used in conjunction with the hemostatic materials. The pieces of fibrin foam and of soluble cellulose were soaked in thrombin, taken from the solution, rolled in sulfadiazine powder, and then placed in the incision in the liver. Procedure 3 was carried out in five monkeys, which were autopsied at the following intervals after operation: 8 days, 5½, 8, 9, and 12 weeks.

Pathologic studies: At 8 days, a portion of fibrin foam 6 by 5 mm. remained. While the fibrin foam was more compact than unimplanted material, the meshes were still present and were filled with blood clot, which was disintegrating. No giant cells and very few polymorphonuclear leucocytes were seen at the periphery. Little proliferation of connective tissue was seen. The pieces of soluble cellulose measured 3 by 7 mm. The tissue reaction to the soluble cellulose was almost identical with that induced by the fibrin foam.

In the animals sacrificed at 5½, 8, 9, and 12 weeks, the incisions in the liver were entirely healed. No fibrin foam or soluble cellulose could be made out. There were no residua in the scar which could be correlated with the implantation of either hemostatic agent or with the use of sulfadiazine.

Result: When fibrin foam with thrombin was rolled in sulfadiazine powder and implanted in the liver, the tissue reactions and absorption of the materials were identical with those found when no sulfadiazine was used. The same was true when sulfadiazine was used with soluble cellulose.

Procedure 4.—After a small midline abdominal incision had been made, a cube of fibrin foam with thrombin 0.7 cm. in each dimension was placed between the traumatized liver and the diaphragm. In another area, a piece of soluble cellulose of the same size was placed between the liver capsule and the diaphragm. The abdominal incision was closed in layers. This procedure was carried out in five monkeys, which were autopsied at 3 (2 animals), 4½, 8, and 12 weeks.

Pathologic studies: In the monkeys examined at 3 weeks, definite remnants of fibrin foam and of soluble cellulose were found on the surface of the liver but in neither case were they adherent to the diaphragm. The residual fibrin foam was more compact than unimplanted fibrin foam but its meshlike character was preserved throughout. There was a thin but complete fibrous tissue capsule about the fragment. At the margin between the fibrous tissue and the fibrin foam, as well as within the fibrous tissue, there were considerable numbers of mononuclear cells, some lymphocytes, and a very few polymorphonuclear leucocytes. The most conspicuous feature of the tissue reaction, however, was the presence of a line of giant cells about the fibrin foam at the periphery of the mass. The giant cells formed a layer one giant cell deep about the portion of the fibrin foam in contact with the superior surface of the liver but were almost entirely absent on the surface toward the diaphragm. Only a few giant cells were seen within the deeper portions of the fibrous tissue. No adhesions were found between the fragment and the diaphragm, the fibrin foam having become adherent only to the liver. Less residual soluble cellulose was recovered than fibrin foam in these specimens. The tissue reaction to it, however, had many points of similarity. Residual soluble cellulose was found adherent to the liver but not to the diaphragm. About the material was a layer of fibrous tissue somewhat wider than that surrounding the fibrin foam. The center was com-

posed of bits of soluble cellulose, usually surrounded by giant cells without demonstrable soluble cellulose fragments, numerous large mononuclear cells, a few lymphocytes, and very rare polymorphonuclear leucocytes.

At 4½ weeks, no fibrin foam could be identified. In the place where it had been put, the liver capsule was very slightly thicker than elsewhere, the thickening being due to an increase in fibrous tissue. The soluble cellulose was also entirely absorbed. There was the same fibrous tissue thickening of the capsule as with fibrin foam, although it was slightly greater in the case of the soluble cellulose. At one point there were a few lymphocytes and a small group of giant cells within the fibrous tissue. No adhesions to the diaphragm had formed.

In the monkeys examined 8 weeks after operation, the only means of identifying the region in which fibrin foam had been placed was a slight fibrous thickening at one point. One very small adhesion to the diaphragm was noted. There was a similar thickening of the capsule without diaphragmatic adhesion in the region where soluble cellulose had been placed. A very small group of giant cells and lymphocytes was seen in the fibrous tissue.

No traces of fibrin foam, soluble cellulose, or reaction to these materials could be identified 12 weeks after operation.

Result: When fibrin foam was placed between the liver and diaphragm, a foreign body reaction was elicited which was much less extensive, however, than the reaction to a single black silk suture. This subsided quickly, leaving only a very slight thickening of the liver capsule with one adhesion to the diaphragm. The behavior of soluble cellulose was very similar, although the main mass was absorbed somewhat more rapidly than was that with fibrin foam. However, signs of cellular activity persisted longer with soluble cellulose than with fibrin foam.

Procedure 5.—Procedure 4 was repeated with the variation that the fibrin foam and soluble cellulose, after soaking in thrombin, were rolled in sulfadiazine powder. Procedure 5 was carried out in five monkeys which were autopsied at the following intervals after operation: 5½, 8 (two animals), 8½, and 12 weeks.

Pathologic studies: At 5½ weeks the fibrin foam was completely absorbed with only traces of fibrous tissue thickening of the liver capsule and no diaphragmatic adhesions. The soluble cellulose was also completely absorbed, its site being marked by a group of giant cells and lymphocytes as well as a small adhesion to the diaphragm.

At 8 weeks and at 8½ weeks no trace of fibrin foam or soluble cellulose could be found and the areas in which they had been placed showed no adhesions.

In the monkey sacrificed 12 weeks after operation, there was a small adhesion in the region where fibrin foam had been left, but none in the place where soluble cellulose had been inserted.

Result: The simultaneous use of sulfadiazine with fibrin foam with thrombin and soluble cellulose with thrombin did not prevent the absorption of these materials or alter the final result significantly.

Procedure 6.—A stab wound 1 cm. deep was made in the left lobe of the liver (as in Procedure 2) in which was placed a piece of fibrin foam 1 by 1 by 1 cm. soaked in thrombin. The same amount of fibrin foam with thrombin was dipped in a solution of penicillin. This was then similarly implanted in a different area of the left hepatic lobe. Procedure 6 was carried out in one monkey, which was sacrificed 34 days after operation.

Pathologic studies: The fibrin foam with thrombin without penicillin was largely absorbed although a small area of residual fibrin foam was still present.

This was surrounded by the fibrous tissue of the scar closing the line of incision. Giant cells were very rare and infiltration with mononuclear cells and lymphocytes was slight. Sections of the area in which penicillin-soaked fibrin foam with thrombin had been placed showed the same histologic appearance.

Result: In one monkey, the use of penicillin solution at the same time as fibrin foam with thrombin resulted in tissue reactions identical with those to fibrin foam with thrombin in the absence of penicillin.

Procedure 7.—A stab wound 1 cm. deep was made in the left lobe of the liver (as in Procedure 2). A piece of fibrin foam 1 by 1 by 1 cm. was soaked in thrombin and inserted in the stab wound. In another portion of the left lobe, a piece of monkey's rectus muscle 1 by 1 by 1 cm. (not soaked in thrombin) was similarly implanted. Procedure 7 was carried out in three monkeys, which were sacrificed 3, 7, and 14 days after operation.

Pathologic studies: At 3 days, the piece of fibrin foam measured 4 by 3 mm. It was composed of meshes of deep blue-staining material, the interstices containing blood clot near the liver tissue and appearing empty at the center. A few scattered polymorphonuclear leucocytes, mononuclear leucocytes, and lymphocytes were present in the adjacent liver tissue but reaction to the fibrin foam was very slight. Giant cells were not encountered. The muscle fragment measured 7 by 3 mm. The general histologic features of the muscle were clearly visible, although disintegration had begun. About the fragment was some blood clot. Within the adjacent liver tissue, polymorphonuclear leucocytes were numerous and a few mononuclear cells and lymphocytes were also seen. Similar cells in moderate numbers were found scattered through all parts of the muscle implant. A small group of giant cells was seen in one area.

In the monkey sacrificed at 7 days, the remnant of fibrin foam measured 3 by 3 mm. Polymorphonuclear leucocytes were very rare but mononuclear cells and lymphocytes were somewhat more numerous than in the specimen at 3 days. There was some proliferation of fibroblasts about the fibrin foam. A small number of giant cells had become isolated from the main mass. The muscle fragment measured 7 by 3 mm. Disintegration of muscle fibers had progressed much further than at 3 days. There was partial replacement of the fragment by fibrous tissue. Polymorphonuclear leucocytes were few, but scattered lymphocytes and mononuclear cells were found in moderate numbers both within the muscle fragment and at its periphery. Giant cells were present in small numbers.

At 14 days, the remaining fibrin foam measured 3 by 3 mm. The fibers had become more compact but the netlike character was clearly shown. The periphery of the fragment was surrounded by numerous giant cells, lymphocytes, mononuclears, and a few polymorphonuclear leucocytes. There was some proliferation of connective tissue about the fibrin foam. The muscle fragment measured 6 by 4 mm. Further stages of the process outlined at 7 days were found in this specimen. Many partially disintegrated muscle fibers were seen; fibrous tissue surrounded the fragment and was replacing the muscle fibers. Giant cells were occasionally encountered. About the fragment, lymphocytes and mononuclear cells were numerous, while polymorphonuclear leucocytes were few; only scattered cells of these types were found within the fragment itself.

Result: The tissue reaction to muscle in the liver was much greater than the reaction to fibrin foam with thrombin. Fibrin foam with thrombin tended to be removed with relatively mild reaction while muscle tended to be replaced by fibrous tissue.

Procedure 8.—The liver was exposed as in the other procedures. A piece of fibrin film 2 by 2 cm. square was placed on the diaphragmatic surface of the liver, being held there by black silk sutures at each corner. At the same time, a cube of fibrin foam with thrombin, 0.8 cm. on each side, was placed between the film and the liver capsule. This procedure was carried out in two monkeys, one being sacrificed 107 days and the other 154 days after operation.

Pathologic studies: At 107 days, the fibrin foam with thrombin and the fibrin film had been completely absorbed. There were a few scattered lymphocytes and mononuclear cells in the region but giant cells were not found. The fibrin film had been replaced by fibrous tissue, which was much less in amount than the original fibrin film. This fibrous tissue was dense at the periphery and very vascular at the center. The adjacent portions of the liver capsule were slightly thickened, owing to increase in connective tissue. There were a few delicate adhesions between the diaphragm and the liver capsule in this region.

One hundred fifty-four days after operation neither fibrin foam with thrombin nor fibrin film could be identified. The site of operation could be located only by the presence of the black silk sutures. No adhesions or detectable thickening of the liver capsule was found.

Result: The simultaneous use of fibrin foam with thrombin and fibrin film did not prevent the absorption of both or alter the final reactions to either.

Fibrin Foam With Thrombin in the Peritoneal Cavity

If fibrin foam with thrombin is to be used as a hemostatic agent in abdominal surgery, it is important to determine to what extent the material is a peritoneal irritant, whether it is absorbed in the peritoneal cavity, and whether its presence leads to the formation of adhesions. Opportunities for controlled study of these questions in the clinic are very few. Accordingly, a series of experiments was set up in monkeys to test these possibilities.

Procedure 9.—A piece of fibrin foam with thrombin, measuring 0.8 cm. on each side, was placed on the surface of the pelvic peritoneum to the left of the uterus and a piece of soluble cellulose with thrombin of the same size was placed to the right of the uterus. This procedure was carried out in five monkeys which were sacrificed 5, 8, 8½, and 12 weeks after operation.

Pathologic studies: In the monkeys sacrificed at 5, 8, 8½, and 9 weeks, no adhesions were found and no traces of fibrin foam or soluble cellulose could be made out. Since no sutures had been used to mark the place where the materials had been left on the surface of the peritoneum, the sites could not be identified with certainty. The entire surface of the pelvic peritoneum was uniformly smooth and glistening. When the monkey was examined at 12 weeks after operation, no residual fibrin foam or soluble cellulose was found. There were no adhesions where soluble cellulose had been left but a few fine adhesions were seen in the region of the pelvic peritoneum where fibrin foam had been placed. Histologic sections showed these adhesions to be richly vascular. About them on the surface of the pelvic peritoneum was a reaction to cotton fibers, evidently from the surface of the sponge placed in the pelvis during operation. There was no evidence that the adhesions were due to the fibrin foam.

Result: At 5 weeks and later, both fibrin foam with thrombin and soluble cellulose with thrombin had been absorbed from the pelvic peritoneum without demonstrable residual reaction.

Procedure 10.—Procedure 9 was repeated with the variation of sulfadiazine being employed in conjunction with both the hemostatic materials. Pieces of fibrin foam and of soluble cellulose were soaked in thrombin, taken from the

solution, rolled in sulfadiazine powder, then placed on the pelvic peritoneum as in Procedure 9. Procedure 10 was carried out in five monkeys which were autopsied 5, 8, 8½, 9, and 12 weeks after operation.

Pathologic studies: At 5 weeks, fine adhesions were found about the sites where both fibrin foam and soluble cellulose were left. Histologic studies showed that these adhesions were formed about fibers of cotton, as in one monkey in Procedure 9. No remnants of fibrin foam or of soluble cellulose were seen. In the monkeys autopsied at 8, 8½, 9, and 12 weeks after operation, no residual fibrin foam or soluble cellulose was encountered. There were no adhesions and the pelvic peritoneum was smooth and glistening throughout.

Result: The use of sulfadiazine with fibrin foam and with soluble cellulose did not prevent the absorption of either hemostatic agent and did not lead to the formation of adhesions.

Fibrin Foam With Thrombin in the Abdominal Wall

Ordinarily, fibrin foam with thrombin would not be needed in the abdominal wall, where the bleeding is satisfactorily and expeditiously controlled with ligation. However, in patients with jaundice, hemophilia, and a few other conditions, there is troublesome oozing from large surfaces on which conventional methods of hemostasis are ineffective. On such surfaces a coating of fibrin foam with thrombin might be useful. Since the tissue reactions to fibrin foam with thrombin are minimal in regions such as the brain, liver, and peritoneum, it would not be expected that they would be significant in the abdominal wall. However, a few studies were carried out in guinea pigs to test this point.

Procedure 11.—Guinea pigs weighing about 350 grams were anesthetized with ether. Two incisions 0.7 cm. long were made in the abdominal skin, one on each side of the midline. Dissection was carried out laterally along the superficial fascia for 2 to 3 cm. Cubes of fibrin foam with thrombin 0.5 cm. on each side were placed as far laterally as possible. The incisions were closed with a single black silk suture. This procedure was carried out in 3 guinea pigs, which were sacrificed at 3, 7, and 14 days after operation.

Pathologic studies: In the specimen obtained 3 days after operation, the fragment of fibrin foam measured 0.5 by 0.2. Its meshes were smaller than those of unimplanted fibrin foam. The centers of the fibers retained the methylene blue, while the edges were stained with phloxine. Polymorphonuclear leucocytes were scattered in small numbers through the meshes of the fibrin foam and were somewhat more numerous at the periphery. No giant cells were seen and very little cellular infiltration was found outside the fragment of fibrin foam, other than that accounted for by the trauma of inserting the material. At 7 days the residual fragment measured 0.3 by 0.2 cm. The fibers were being broken up and more of them took the phloxine stain. Considerable infiltration with lymphocytes and mononuclear cells as well as a few polymorphonuclear leucocytes was present together with some connective tissue proliferation about the fragment. There were no giant cells. In the guinea pig sacrificed at 14 days, no fibrin foam was seen grossly, although a few isolated bits of fibers could be made out on microscopic study. The infiltration with lymphocytes and mononuclear cells was less than at 7 days and the area about the original site contained connective tissue which was more compact than in the preceding specimen.

Result: In three experiments, the absorption and tissue reaction to fibrin foam with thrombin were similar to those described in the liver, central nervous system, and elsewhere.

A large series of experiments was carried out in the abdominal wall by this technique to test differences in tissue reaction when the conditions varied under which the fibrin foam was manufactured. These all led to essentially similar results. Only those experiments carried out with the type of fibrin foam with thrombin now used in the clinic have been reported in this paper. However, the other experiments lend support to the conclusion that fibrin foam with thrombin is quickly absorbed from the abdominal wall with no definite increase in scar tissue over that of a simple incision in this area.

Fibrin Foam With Thrombin in the Kidney

In partial resection of the kidney and in nephrotomy, an actively oozing surface is exposed. Hemostasis by means of sutures and other conventional techniques is difficult and often unsatisfactory. Experiments were carried out to determine the effectiveness of fibrin foam with thrombin and to ascertain the tissue reactions in this situation.

Procedure 12.—A lumbar incision was made and the kidney exposed. The capsule was stripped from one pole of the kidney. The pole was then resected, leaving a freely bleeding surface. Fibrin foam with thrombin was placed over the surface, resulting in complete hemostasis. The capsule was sutured over the fibrin foam with thrombin and the wound closed in layers. Procedure 12 was carried out in two monkeys. One died on the twenty-first postoperative day. The other was sacrificed 65 days after operation.

Pathologic studies: The monkey autopsied 21 days after operation had an extensive perirenal abscess which was judged to be the cause of death. Fibrin foam was still present in moderate amount with tissue reaction identical with that described in the liver. At 65 days after operation, the fibrin foam had been completely absorbed. The fibrous tissue of the scar was not larger in amount or different in character from that expected in the healing of a similar wound without fibrin foam.

Result: Fibrin foam with thrombin was effective in controlling the bleeding in resection of the pole of the kidney and was absorbed with negligible tissue reaction.

Procedure 13.—A lumbar incision was made and the kidney delivered into the wound. The renal vessels were compressed with the operator's fingers while a sagittal incision was made in the kidney deep enough to open the renal pelvis. The bleeding surfaces were covered with fibrin foam with thrombin and the capsule of the kidney closed with black silk sutures (Fig. 7). No ligatures were used on the incised surfaces of the renal parenchyma, even on the actively bleeding arteries, since fibrin foam with thrombin brought about complete hemostasis. The capsule was sutured, however. This procedure was carried out in four monkeys, which were sacrificed 3, 7, 10, and 14 days after operation and in one cat, which was sacrificed at 322 days.

Pathologic studies: In the monkey sacrificed at 3 days, there were about 3 c.c. of dark red fluid about the kidney, which was loosely adherent to the perirenal tissue along the suture line. Histologic study showed that the interstices of the fibrin foam were filled with blood clot. At the periphery of the fibrin foam, there was moderate infiltration of polymorphonuclear leucocytes with a few lymphocytes and mononuclear cells (Fig. 8).

In the specimens at 7, 10, and 14 days there was no fluid at the operative site. The suture line was progressively more adherent to the perirenal tissues. Fibrin foam persisted in all three specimens, but decreased in amount as the

time since operation lengthened. The tissue sequences in response to the fibrin foam were the same as those described in the liver. Occasional giant cells were found in the specimen at 7 days; they were numerous at 10 days and were less at 14 days, at which time a large part of the fibrin foam had been absorbed. In the cat sacrificed 322 days after operation, the kidney was not abnormally adherent to the perirenal tissues. The kidney which had been incised was slightly smaller than the opposite kidney. The scar of pyelonephrotomy was identified as a thin white line, not differing grossly or microscopically from the scar of a similar incision in which fibrin foam with thrombin had not been used.

A.



B.

Fig. 7.—Procedure 13. *A*, Free bleeding from the surface of the kidney incised in the sagittal plane. *B*, Complete hemostasis after application of fibrin foam with thrombin. The capsule has been sutured but hemostasis was complete before doing so.

Result: Fibrin foam with thrombin was effective as a hemostatic agent in experimental renal resection and pyelonephrotomy and was absorbed with slight tissue reaction.

Fibrin Foam With Thrombin in the Lung

There are occasions in thoracic surgery, notably in dealing with the lung parenchyma, when capillary and venous bleeding is difficult to control by the conventional methods of hemostasis. Experiments were set up to test the efficacy of fibrin foam with thrombin as a hemostatic agent in the lung and the tissue reactions induced by it in that location.

Procedure 14.—The operations were carried out under nembutal anesthesia; the animals were intubated so that oxygen and carbon dioxide under positive pressure could be used when necessary. The right thoracic cavity was opened in the seventh interspace. After drawing the right lower lobe of the lung into the wound, an incision was made 1.5 cm. long, care being taken to avoid the larger bronchi. A piece of fibrin foam with thrombin 1.5 by 0.7 by 0.5 cm. was placed in the wound, which was closed with one or two black silk sutures. Effective hemostasis was secured in all animals (Fig. 9). The thoracic cavity was closed in layers, all air being aspirated and the lung reinflated with positive pressure. This procedure was carried out in five monkeys. One of these died 5 minutes after operation and the others were sacrificed at 7, 10, 14, and 24 days. It was also performed on a cat, sacrificed at 356 days after operation.

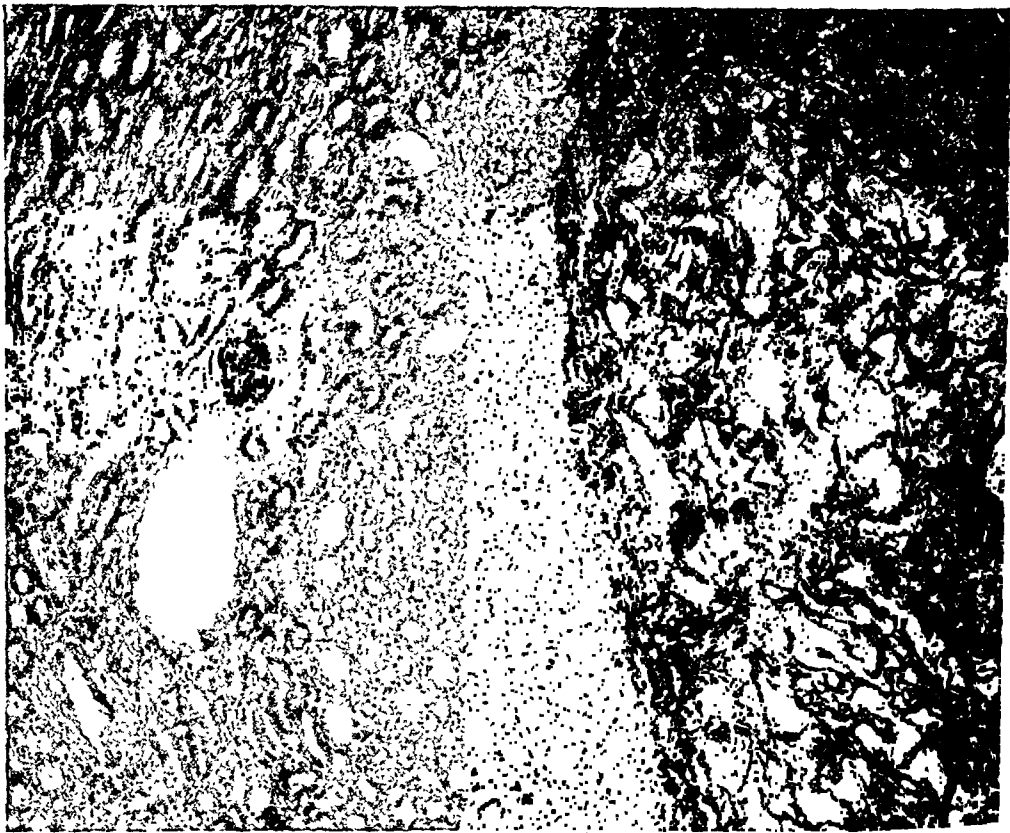


Fig. 8.—Procedure 13. The appearance of fibrin foam 3 days after its application as a hemostatic agent in experimental pyelonephrotomy. (Phloxine methylene blue stain, $\times 96$.)

Pathologic studies: In the specimen 5 minutes after operation, the fibrin foam was unchanged in general structure from the unimplanted material. Some of its interstices were filled with fresh blood clot; there was no demonstrable reaction in the surrounding tissue. At 7 days, the fibrin foam was more compact than when implanted. A mild infiltration with polymorphonuclear leucocytes, and a few mononuclear cells and lymphocytes, were seen about it; occasional giant cells were present. Ten days after operation (Fig. 10) the number of giant cells had increased, while at 14 days they were less numerous than at 10 days. Fibrous tissue reaction was slight. In the cat sacrificed at 356 days, the well-healed scar was not adherent to the parietal pleura. It contained no fibrin foam and showed no characteristics which could be correlated with the use of this material at the time of operation.

Result: Bleeding from experimental incisions in the lung parenchyma was controlled by the application of fibrin foam with thrombin. The tissue reactions to the hemostatic material were mild.

COMMENT

These studies have shown that fibrin foam with thrombin is an effective hemostatic agent in the liver, peritoneal cavity, abdominal wall, kidney, and lung of experimental animals. Only a slight tissue reaction is elicited and, in the end result, the amount of fibrous tissue due to the presence of the fibrin foam

A.



B.

Fig. 9—Procedure 14. A, Experimental incision in the lung B, Hemostasis secured by packing the incision in the lung with fibrin foam with thrombin

with thrombin is so small that it cannot be regarded as clinically significant even when a large mass of fibrin foam with thrombin is used. The fibrin foam with thrombin is completely absorbed in about 5 weeks and sometimes at a shorter interval after implantation. The tissue reaction is not altered by the

use of sulfadiazine or penicillin at the same time. The use of fibrin film and fibrin foam with thrombin does not alter the tissue reaction and final results to either.

Fibrin foam with thrombin elicited very much less tissue reaction than muscle fragments of the same size. The tissue reaction to soluble cellulose with thrombin and fibrin foam with thrombin are about the same qualitatively and quantitatively. The choice between these two substances must be made on the basis of operative convenience rather than upon the extent of tissue reaction. The present studies of this tissue reaction to soluble cellulose are in complete agreement with Frantz.⁵ The material used by us was the earlier type of Frantz, designed to be soaked in thrombin, no experiments with her newer type⁶ are included in this report. It is difficult to evaluate the significance of



Fig. 10—Procedure 14. The appearance of fibrin foam 10 days after its application as a hemostatic agent in an incision in the lung parenchyma. (Phloxine methylene blue stain, $\times 96$)

a few adhesions described both to fibrin foam with thrombin and to soluble cellulose. The mere procedure of exposing the liver often results in the formation of an equivalent amount of adhesions and sometimes more than is seen in this series of animals. In some instances, the adhesions could be shown to be due to cotton fibers, presumably from the gauze used at operation; in others, they could not. Such findings, however, emphasize the safety of fibrin foam with thrombin for they indicate that a large mass of fibrin foam with thrombin leaves less reaction than a group of cotton fibers so small and so few as to be overlooked by the surgeon.

On the basis of this experimental work, fibrin foam with thrombin was recommended for clinical trial in general surgery.

CLINICAL STUDIES

Fibrin foam with thrombin was used first in general surgery at The Children's Hospital and the Peter Bent Brigham Hospital, Boston, Mass. It was then released to several surgical clinics throughout the country. Reports of the use of fibrin foam with thrombin in various operations of general surgery and the surgical specialties other than neurosurgery and dental surgery now number 240. This discussion is based on the reports from these clinics as well as on our own experience.

To date, fibrin foam with thrombin has been used oftener in the liver and biliary passages than elsewhere in general surgery because of the frequency with which oozing surfaces, difficult to control by conventional methods of hemostasis, are encountered in these locations. Bleeding from the bed of the gall bladder during cholecystectomy is at times troublesome. Fibrin foam with thrombin quickly and effectively controls the capillary bleeding, thus decreasing blood loss, reducing the length of the operation, and sometimes allowing closure without drainage, since the field can be left entirely dry. In cholecystitis, especially in the acute phase, it may be necessary to remove the gall bladder from the fundus toward the cystic duct. This method of cholecystectomy has been regarded as safer than other techniques because there is less chance of injuring the common bile duct but it renders hemostasis more difficult. The use of fibrin foam with thrombin, therefore, obviates the principal objection to this type of operation. During exposure and exploration of the common bile duct, there is occasionally troublesome bleeding from capillaries and small venous channels which is difficult to control with sutures and which prolongs the operation considerably. Such bleeding is easily and expeditiously stopped by the application of fibrin foam with thrombin.

Bleeding from the cut surface of the liver is so troublesome that many surgeons hesitate to remove even a small portion of the liver parenchyma; resection of larger areas are attended by serious hemorrhage. Experience has shown that biopsy of the liver is a simple procedure when the area of incision is packed with fibrin foam with thrombin. If necessary, hemostatic material may be held in place by a suture. Occasions demanding resection of large portions of the liver are exceptional. In a patient at the Peter Bent Brigham Hospital, fibrin foam with thrombin greatly facilitated an operation of this type.

CASE REPORT

A 45-year-old woman came to the hospital because of pain after meals, weakness, and tarry stools for months. A mass about 12 cm. in diameter was palpated in the left upper quadrant of the abdomen. Roentgenograms of the gastrointestinal tract showed a filling defect in the midportion of the stomach; the stools were positive for blood by the guaiac test. Abdominal exploration revealed a large gastric neoplasm which was attached to the left lobe of the liver. Since the lesion extended high in the stomach, the abdomen was closed and radical resection by a transthoracic approach was undertaken 3 weeks later, at which time subtotal gastrectomy and partial hepatectomy were carried out. A portion of the left lobe of the liver, measuring 9.5 by 7.4 by 4.8. cm. was removed after through-and-through catgut sutures had been placed and tied. The large vessels were clamped and ligated with figure-of-eight sutures. After this had been completed, the entire cut surface still bled freely from the small vessels. When this surface was covered with fibrin foam with thrombin, all bleeding was controlled. There was no evidence of hemorrhage from the cut surface of the liver during the postoperative course. The patient was last seen 14 months after operation; at that time, she was in good health and there was no evidence of recurrence. In retrospect, it would seem that silver clips would have been more satisfactory for the actively bleeding arteries than figure-of-eight sutures.

Oozing surfaces are occasionally encountered in biopsy or resection of large tumors in various sites; control of these may be time consuming or dif-

difficult to accomplish at all. Ten reports dealing with the use of fibrin foam with thrombin in these locations have made it clear that the material is very effective under such circumstances. During radical resection of two mixed tumors of the parotid gland, fibrin foam with thrombin was found helpful in securing hemostasis. The material is particularly valuable in dealing with these tumors because of the importance of saving all branches of the facial nerve. Since there is often bleeding in the region of this structure, it may be injured in the application of instruments to maintain hemostasis and much time is consumed because of the caution necessary in the placing of each hemostat and suture. The bleeding can be safely and quickly brought under control with fibrin foam with thrombin. There are also two reports of hemorrhage after the removal of portions of rapidly growing retroperitoneal tumors for microscopic study; in both instances the use of fibrin foam with thrombin produced satisfactory hemostasis after sutures had proved inadequate for the purpose. In three instances, the removal of large pelvic tumors left areas of peritoneum on the pelvic wall or on the bowel surface where oozing was difficult to control. Thin sheets of fibrin foam with thrombin stopped the bleeding promptly in each patient. The other three reports on the use of fibrin foam with thrombin in dealing with tumors are concerned with its use in resections of carcinomas of the head of the pancreas. The proximity of many important structures in this region makes the use of sutures difficult and hazardous. Control of capillary bleeding is more effective and less dangerous when fibrin foam with thrombin is used than when sutures are employed. Actively bleeding arteries must be ligated, as well as the larger veins.

Three additional reports of the use of fibrin foam with thrombin in biopsy of the pancreatic parenchyma indicate that the procedure is greatly simplified when this material is employed for hemostasis.

Biopsy of the spleen is attended by so much bleeding that it is seldom attempted when sutures are depended upon for control of bleeding. This may be carried out readily when fibrin foam with thrombin is used for hemostasis, as illustrated in the following report from the Peter Bent Brigham Hospital.

CASE REPORT

A 58-year-old woman entered the hospital because of intermittent fever, weight loss, malaise, and enlargement of the abdomen. On physical examination, the patient was found to have a greatly enlarged spleen. Biopsy of an enlarged cervical lymph node showed the presence of tuberculosis. A diagnosis of primary splenic tuberculosis was entertained and biopsy of the spleen was performed under local anesthesia. At operation, the spleen was found to be smooth, glistening, and bluish red in color. It was soft but tense; no tubercles were seen or palpated. Tissue was removed from the spleen for histologic study by making an elliptical incision 1.5 cm. in length and 1 cm. in depth. The splenic tissue was very friable and the site of the biopsy bled profusely. Fibrin foam with thrombin was packed into the incision and excess fluid removed with suction through a gauze sponge. All bleeding ceased within one minute. The material removed for histologic study showed no evidence of tuberculosis. There was no evidence of postoperative bleeding. The patient gradually became weaker and died four weeks after operation. At autopsy the scar of the incision in the spleen was well healed and very small. On histologic examination there was only a small amount of fibrin foam remaining and tissue reaction was minimal. The patient proved to have an unclassified disease of the hematopoietic system.

Fibrin foam with thrombin has been used to reduce the blood loss from oozing in the course of certain gynecologic operations, especially colporrhaphy and hysterectomy. The material was found effective in obtaining prompt hemostasis but the technique of application now used could probably be improved for use in these locations. Fibrin foam with thrombin may occasionally be use-

ful in the control of bleeding along the ureters and in a few other sites where the application of hemostats holds special dangers. However, it would seem that most of the bleeding in these operations can be controlled by sutures and by meticulous surgical technique, without the use of fibrin foam with thrombin. Among the instances in which fibrin foam with thrombin was used in gynecologic surgery, the following one from the Parkway Hospital, Brookline, is of particular interest.

CASE REPORT

A 48-year-old woman was admitted to the hospital for a vaginal plastic procedure. On the day before operation, she was given 200 mg. of dicumarol, as a prophylactic against venous thrombosis and embolism. The vaginal repair was carried out successfully. On the fourth postoperative day, 0.8 c.c. of furmethide was given in order to help empty the bladder. Since the prothrombin time, by Quick's method, was 40 seconds (control, 21 seconds) the patient also received 200 mg. of dicumarol. There was an unusually severe reaction with defecation, sweating, and faintness; a diffuse skin rash developed. On the eighth postoperative day, bright vaginal staining was noted; the prothrombin time was 238 seconds (control, 38 seconds). Examination showed oozing along the suture line in the anterior vaginal wall. Fibrin foam with thrombin was applied with immediate hemostasis; 64 mg. of vitamin K were also given intravenously. Eight hours later, the bleeding recurred, and the vagina was packed with gauze. On the following day, the incision was resutured because of continued bleeding. At this time, the prothrombin time was 180 seconds (control, 25 seconds); 64 mg. of vitamin K were again administered. The next day, an attempt was made to control the bleeding by instilling a solution of thrombin in the vagina, which resulted in temporary cessation of the oozing. This procedure was repeated later the same day and was followed by immediate hemostasis lasting 16 hours. The following day the prothrombin time was 115 seconds (control, 29 seconds). With the recurrence of vaginal bleeding another instillation of thrombin solution was given; this produced permanent hemostasis. The prolongation of the prothrombin time was out of proportion to the amount of dicumarol administered. While the hemostatic action was at first temporary, it finally controlled the hemorrhage and made transfusions unnecessary.

The course of events shows that local hemostasis can be secured by the application of human thrombin in a patient with elevated prothrombin time. It also illustrates the fact that thrombin is the active hemostatic agent while fibrin foam is a matrix to hold it. When very large amounts of thrombin are required and the absorption of the material holding the thrombin unimportant, thrombin-soaked gauze may be preferable to fibrin foam with thrombin.

Considerable use of fibrin foam with thrombin has been made in genitourinary surgery. In enucleation of the prostate by the suprapubic transvesical route, the control of hemorrhage from the prostate bed has been a difficult and important problem. If it is possible to control the bleeding completely at the time of operation, there would be no need for hemostatic bags and similar appliances. The convalescence would therefore be shorter and complications less likely. A hemostatic material for use in this location either should be soluble in urine or should disintegrate so that no fragments would remain to serve as a nidus for the formation of calculi. The substance should also adhere to the wall of the prostatic bed after application.

Observations on the use of fibrin foam with thrombin in prostatectomy have been carried out at the Peter Bent Brigham Hospital. The studies indicate that fibrin foam with thrombin is satisfactory under these conditions and that it may be further improved by variations in methods of its preparation. A detailed report is being prepared by Dr. W. C. Quinby. The use of fibrin foam with thrombin as a hemostatic agent in prostatectomy is illustrated by the following case report.

CASE REPORT

A 58-year-old man came to the hospital because of urination every half hour to hour, nocturia three times each night, dysuria, decreased caliber of the urinary stream, and inability to empty the bladder completely. These difficulties had been present for more than one year. On examination, both lateral lobes of the prostate were found enlarged and there was a large intravesical median lobe. The prostatic urethra measured 5 cm. in length. There were 100 c.c. of residual urine, which was free from infection. Under spinal anesthesia, suprapubic prostatectomy was carried out without preliminary drainage of the bladder. The prostate was easily enucleated; the bleeding was controlled by placing small strips of fibrin foam with thrombin along the prostatic urethra. Hemostasis was very satisfactory. The bladder was then closed around a suprapubic catheter and the abdominal wound reunited. No hemostatic bag was used. On the first postoperative day, the urine from the catheter was almost free of blood. The catheter was removed on the third day following operation; the patient immediately voided a normal stream of urine. Sutures were removed from the abdominal wound on the eighth postoperative day. When the patient was discharged on the twelfth day, the wound was well healed and the urinary stream entirely normal.

Rather frequently, in thoracic surgery, oozing surfaces are encountered, the bleeding from which is difficult to control by conventional techniques. One instance is in dealing with extensive adhesions between the visceral and parietal pleurae. As the lung is dissected free from the chest wall, troublesome oozing results. When packing is used to secure a dry field, the operation is considerably prolonged. These areas of bleeding were easily and quickly controlled when they were covered with thin sheets of fibrin foam with thrombin. The use of this hemostatic agent shortened the operation and resulted in a dry field at the time of closure.

One of the most important uses of fibrin foam with thrombin in thoracic surgery is for the control of capillary and venous bleeding in operations for removal of mediastinal tumors. It is sometimes hazardous to use sutures in the mediastinum because of the proximity of important anatomic structures. Such bleeding is readily controlled by means of fibrin foam with thrombin. More important is the use of this hemostatic agent in the beds of the mediastinal tumors. Here venous and capillary bleeding may create a serious situation analogous to the problems confronting the neurosurgeon in dealing with the beds of intracranial tumors. Fibrin foam with thrombin not only controls the bleeding quickly and completely but also at times permits the removal of large tumors in toto which could not otherwise be attacked successfully. This is illustrated by the following case report.

CASE REPORT

A 28-year-old man had a routine roentgenogram of the chest in the course of a general physical examination. There were no symptoms of any kind. The roentgenogram showed a large mass in the chest attached to the posterior mediastinum. Exploration was carried out. On separating the pleura a tumor, measuring approximately 17 cm. long and 12 cm. wide, was exposed. The ovoid tumor filled most of the posterior portion of the right thorax and extended from the hilus to the chest wall. It was attached to the surrounding tissues all along its surface. The size of the neoplasm made exposure difficult. Resection, however, was decided upon and carried out as carefully as possible, the entire tumor being removed in so far as could be determined macroscopically. The bed of the tumor was a mass of bleeding venous sinusoids. Attempts were made to control the bleeding by pressure and saline-soaked sponges. Only partial and temporary hemostasis was accomplished, for the bleeding recurred when the sponges were removed. This procedure occupied one hour. The blood pressure began to fall in spite of transfusions. Fibrin foam with thrombin was then placed over the entire bleeding surface, three bottles being used. Hemostasis was prompt and complete. The pleura was closed over the fibrin foam. The patient died on the day after operation. At autopsy there was no significant hemorrhage. Histologic study showed that the tumor was a rapidly growing fibrosarcoma.

In orthopedic and traumatic surgery, there are a few special situations in which it is important to have an absolutely dry field at the completion of the operation. A thin sheet of fibrin foam with thrombin readily controls the bleeding from the bone in amputations, with the result that no hematomas form in the wounds and the stumps are in excellent condition. When skin grafts are required in amputations, especially in revising amputation stumps, fibrin foam with thrombin controls the bleeding from the bone and soft tissues, leaving an absolutely dry field. For the same reason, this hemostatic agent has proved of value in arthroplasties. As in other types of surgery, fibrin foam with thrombin should be regarded as a supplement to conventional methods of hemostasis, and not as one to supplant meticulous care with tissues.

Persistent bleeding from injuries or operations in patients with hemophilia has long been a troublesome problem to surgeons. A large variety of local hemostatic agents have been used with little or no success and transfusions have been necessary for the most trifling wounds. While experience with fibrin foam with thrombin as a local hemostatic agent in hemophilia has thus far been limited to six instances, its value has been so clearly demonstrated in each that it seems to be the agent of choice in dealing with these lesions. In three patients, persistent bleeding from chronic ulcers of the leg was completely and permanently controlled by a single application of fibrin foam with thrombin. In another patient with hemophilia, this material stopped the bleeding from a laceration of the tongue, a large clamp being used to hold it in place. There were two instances in which lacerations of the extremities had bled persistently for more than 72 hours in spite of transfusions. In both patients, the application of fibrin foam with thrombin produced permanent hemostasis within a few minutes. Fibrin foam with thrombin has also been shown to control bleeding after extraction of teeth in patients with hemophilia. This experience as well as other studies on the use of fibrin foam with thrombin in dental surgery will be reported by Dr. P. K. Losch. It should be pointed out that hemostasis by fibrin foam with thrombin in patients with hemophilia is purely local and does not in any way affect the abnormality of the blood primarily at fault.

The present package in which fibrin foam with thrombin is now supplied for clinical use contains three bottles. One contains pieces of fibrin foam; the second, thrombin in the dry state; the third, physiologic saline solution. At the time of operation, about 10 c.c. of the saline solution are withdrawn by syringe and placed in the bottle of thrombin. The thrombin dissolves rapidly. The thrombin solution and the rest of the saline solution are mixed in a sterile basin on the operating table. Pieces of dry fibrin foam are cut to the size and shape required. They are then placed in the thrombin solution which quickly permeates the fibrin foam because of the porosity of the material. Saturation of the fibrin foam is rapid, being complete in less than two minutes. The permeation of the material is accompanied by a moderate amount of shrinkage, for which allowance must be made in cutting the fibrin foam. The fibrin foam is left in the thrombin solution ready for application as required in the course of the operation. Should more fibrin foam be required than was anticipated, an additional supply could be prepared within three minutes. It is important that the saline solution used to dissolve the thrombin be at room temperature or below and that it be kept away from heated radiators because the thrombin activity is rapidly destroyed at higher than room temperatures. The thrombin solution should be freshly prepared each day.

The techniques used in applying fibrin foam with thrombin to a bleeding surface must necessarily vary with the location on which it is used. In some

places it is desirable to employ thin sheets to cover a wide surface with a minimal amount of the material, while in tumor beds and other oozing cavities it may be advantageous to use much larger pieces. In general, the thrombin-soaked portions of fibrin foam are pressed into place on the bleeding surfaces by means of gentle pressure through cotton or gauze. The excess fluid is removed by suction. The cotton or gauze is then lifted away from the underlying fibrin foam which must be left in place since the clot which is formed is partially within the substance of the fibrin foam. The fibrin foam can be moulded to the shape of the tissue surface and will retain the configuration in which it has been pressed. Bleeding will recur if the fibrin foam is removed. However, if large masses of fibrin foam are used to fill a cavity, such as a tumor bed, it is possible to cut away the central portion without disturbing the freshly formed clot since this lies largely at the region of contact between the fibrin foam and the tissue. The reason for removing the central portion of large masses of fibrin foam is that it favors the rapid disappearance of the material. The final tissue reaction to a very large mass of fibrin foam is so slight as to be inconsequential clinically. It is clear, however, that the rate of disappearance of the material is more or less proportional to the volume left in place. Small fragments will disappear in 7 to 10 days, while it may take 4 to 6 weeks for larger masses to be completely absorbed.

Since fibrin foam with thrombin is a relatively new hemostatic agent it is apparent that its usefulness may often be increased by modifications of the technique herein presented which has been developed largely for the use of the material in neurosurgery. It is possible to prepare in the chemical laboratory a variety of fibrin foams differing in texture, porosity, and persistence time in the tissues. It may well be that in certain locations some of these may eventually prove more useful than the form now supplied.

The wide variety of operations in which fibrin foam with thrombin has been used indicates the general usefulness of the material. A contraindication to the use of this material is in the nose and throat of unconscious patients, or of those with diminished or absent gag reflex. The inhalation of bits of fibrin foam, especially when coated with bacteria containing mucus, would be likely to carry infection to the bronchi and pulmonary tissues.

SUMMARY

Experimental studies have shown that fibrin foam with thrombin is an effective absorbable hemostatic agent in the liver, peritoneal cavity, abdominal wall, kidney, and lung. In each of these locations the absorption of the material is accompanied by only slight tissue reaction.

Clinical appraisal of fibrin foam with thrombin as an absorbable hemostatic agent in general surgery has been carried out in 240 patients. It has proved effective in controlling oozing surfaces and venous bleeding under a wide variety of circumstances, including wounds in patients with hemophilia.

The use of fibrin foam with thrombin should not replace the careful control of bleeding by means of meticulous dissection and adequate placing of sutures. It should be reserved for those particular situations in which an absorbable hemostatic agent is desirable to prevent the injuring of vital anatomic structures or to control oozing which is not easily stopped by conventional methods, as in the beds of tumors and the cut surface of parenchymatous organs.

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THE OCCURRENCE OF BACILLUS HISTOLYTICUS IN ACCIDENTAL WOUNDS WITHOUT RECOGNIZED SPECIFIC INFECTION

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THE title of this paper was suggested by the observations of MacLennan,¹ that in addition to one fatal case of a war wound in the Middle East in which *Clostridium histolyticum* was found as the sole infecting agent, it also "occurred along with other pathogenic clostridia in nine cases of gas gangrene, all of which were fatal."

This contrasts sharply with our own recent experience in the study of civilian wounds^{2, 3} in which we found *Bacillus histolyticus* in 18 cases out of approximately 2,500 wounds. Only 1 of these 18 cases (Case 1) resulted in death, which was attributed at the time not to *B. histolyticus* but to *Bacillus perfringens*. I have been privileged to see only one of these cases clinically but with the aid of my assistants have rechecked all of the cultures of this organism submitted either for identification or confirmation. Permission to present these brief abstracts of the case histories has been granted by the surgeons in charge.

Work done under a contract recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Columbia University.

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COMPOUND FRACTURES

B. histolyticus was recovered in 7 cases of compound fractures.

CASE 1.—J. D. S. (L.G.), a private in the Air Corps, received a compound fracture of the ankle in an automobile accident. He was admitted to the hospital five hours afterward. The wound was badly contused and filled with cinders from the roadside.

The wound was completely débrided. It was treated locally with sulfanilamide and x-ray, and an undesignated amount of gas gangrene antitoxin was administered. But in spite of all treatment the emphysema extended up the fascial planes and it became necessary about three hours after the development of the infection to amputate the leg. The patient died about four days after admission.

Autopsy showed extensive edema of the lungs suggesting hemorrhagic bronchopneumonia.

Smears of the débrided tissues showed streptococci, staphylococci, and gram-positive rods, some with terminal or subterminal spores. Mixed anaerobic cultures in milk gave a stormy fermentation. A transfer of this culture sent to me yielded *Micrococcus epidermidis*, *Bacillus sporogenes*, and *B. histolyticus*. The latter was fully virulent for guinea pigs, producing the characteristic myolysis on intramuscular injection and the peculiar lytic destruction of the skin so characteristic of this species on subcutaneous inoculation. *B. perfringens* was not recovered, but Kuhns* stated that *Clostridium welchii* was present in a blood culture taken at the time of amputation. However, both aerobic and anaerobic cultures taken from the lungs at autopsy were negative but the "findings in the blood vessels, heart and liver were compatible with *Cl. welchii* infection."

CASE 2.—W. B. (M.G.), a white man 48 years old, had a partial avulsion of the right index finger with compound fractures of the second and third phalanges. He was admitted to the hospital within one hour and treatment was started about two and three-fourths hours after the injury. The wound was apparently only slightly contaminated but particles of glass were present. The finger was amputated and sulfadiazine was administered locally, intravenously, and orally. Tetanus antitoxin was also administered. The wound was dressed on the seventh and eleventh days. A mild infection appeared but its character was not determined. Recovery was otherwise uneventful and complete on the eighteenth day.

The débrided tissues yielded a hemolytic streptococcus, Group A, a nonhemolytic streptococcus, *Micrococcus aureus*, *micrococcus albus*, *micrococcus tetragenus*, *Sarcina lutea*, "hay bacillus," *Bacillus pasteurianus*, and *B. histolyticus*, the latter fully virulent.

CASE 3.—D. J. (C.H.), a Negro man 70 years old, suffered a compound fracture of the tibia and fibula and lacerations of the forehead in a street accident. He was treated within one hour. Contamination was regarded as slight. He was given 3,000 units of tetanus antitoxin and 3,000 units of *B. perfringens* antitoxin. The wound on the finger was completely débrided, dusted with sulfanilamide and sulfadiazine, and the bony parts were fixed by plates, screws, and plaster. Sulfadiazine was also given orally and intravenously, a total of 47 Gm. in nine days. The wound on the head was also dusted with sulfadiazine and sutured. The scalp wound healed without complications but the leg became infected and developed a persistent osteomyelitis. There was no union after twenty-three days.

Cultures from the débrided tissues yielded many species of bacteria, among which were identified a nonhemolytic streptococcus, Group D, *Micrococcus varians*, *M. epidermidis*, *Flavobacterium* sp. ?, *Bacillus bifementans*, and *B. histolyticus*, apparently nonpathogenic upon subcutaneous inoculation of a guinea pig.

Unfortunately, through some oversight, no cultures were made after the initial operation.

CASE 4.—A. C. (C.H.), a white man 39 years old, suffered a compound fracture of the lateral malleolus and a slight diastasis of the tibia and fibula. The wound was cleansed, débrided, sprinkled with sulfanilamide, and left open. Sulfadiazine was administered orally at once and occasionally during the following eight days, a total of 51 Gm.

There was no evidence of infection on the twelfth day and although healing was still incomplete the patient deserted and did not return. The débrided tissues yielded a nonhemolytic streptococcus, Group D, *M. epidermidis*, *Micrococcus aurantiacus*, *Bacterium aerogenes*, *Bacillus tertius*, and *B. histolyticus*, fully virulent. On the tenth day a culture showed a nonhemolytic streptococcus, *M. aureus* and a "hay bacillus."

*The data in this case were supplied by Capt. D. M. Kuhns, formerly Chief of the Laboratory Service, Medical Corps, Letterman General Hospital, San Francisco, Calif.

CASE 5.—M. B. (M.G.), a white man 26 years old, suffered a compound fracture of the right radius and ulna, a compound fracture of the lower part of the right leg, and a laceration of the forehead in a railroad yard. He was hospitalized within one hour in fair condition but with impending shock. Operation was started during the next hour. The wounds were contaminated by cinders. It was considered necessary to amputate both the arm and the leg above the sites of fracture. The stumps were dusted with sulfanilamide and closed, the arm without tension, the leg with tension. The laceration on the forehead was also débrided and completely closed. Sulfadiazine was administered systemically, a total of 47 Gm. in thirteen days.

The débrided tissues showed several species of bacteria among which were identified *Bacterium coli*, *Bacterium proteus*, *Bacillus tetani*, and *B. histolyticus*, the two latter fully virulent. The wounds in the head and arm healed in twenty-four days without any clinical evidence of infection except a slight serous discharge in the arm.

On the twelfth day there was still some purulent exudate in the leg and *M. aureus*, *M. albus*, *Bact. coli*, and *Bact. proteus* were found in a culture taken on that day, but on the twenty-fourth day all clinical signs of infection had disappeared. However, the patient remained in the hospital for a total of sixty-five days, when he was discharged using an artificial leg.

CASE 6.—W. J. W. (C.H.), a Negro man 66 years old, suffered a compound comminuted fracture of the left tibia and fibula on a country road. He was brought into the hospital after six hours. He was given 3,500 units of tetanus antitoxin and 4,000 units of *B. perfringens* antitoxin. The wounds were débrided and the fractures were reduced and fixed with Steinmann pins and a plaster cast. Sulfanilamide was used locally and sulfadiazine systemically, a total of 93 Gm. in seventy-five days of hospitalization. This patient had a spiked fever curve with temperatures between 101 and 102° F. but the dressing was not changed until the twenty-fifth day, at which time it was decided to amputate the limb. The record is incomplete from there on; the case was cited as an unsuccessful demonstration of the Trueta-Orr technique.

Cultures from the débrided tissues showed hemolytic streptococci, *Streptococcus fecalis*, Group D, *Micrococcus candidus*, an unidentified "hay bacillus," *B. tertius*, *B. sporogenes*, and *B. histolyticus*, the latter fully virulent. A culture on the twenty-fifth day showed *M. aurantiacus*, *Bact. coli*, *Str. fecalis*, *B. sporogenes*, *Bacillus nonfermentans*, and *B. histolyticus*.

CASE 7.—L. P. (C.H.), a Negro woman 79 years old, had a grossly contaminated compound fracture of the radius and ulna with severe stripping of the periosteum, caused by falling in a field. She was treated in the hospital within one hour, all devitalized tissue and dirt being débrided and the fracture reduced. The wound was dusted with sulfathiazole and left open, fixed under plaster. Tetanus antitoxin, 3,000 units, and *B. perfringens* antitoxin, 4,000 units, were administered. There was no evidence of infection. Recovery was uneventful. The patient was released on the twenty-fifth day.

Cultures of the débrided tissue yielded *B. histolyticus* (fully virulent), *B. bifermentans*, nonhemolytic streptococci, and *B. proteus*. No subsequent cultures were made.

SUMMARY OF COMPOUND FRACTURES

Inspection of Cases 1 to 7 shows that only Case 1 resulted fatally and in that instance death was attributed primarily to *B. perfringens*, as *B. histolyticus* was not suspected until I demonstrated it in a mixed culture. All of the other patients survived, 2 without infection, 1 with a trivial infection, and 3 with serious infections. But with one exception *B. histolyticus* appeared only in the cultures made from the débrided tissues and there was no evidence of lesions which could be attributed to this species. Yet all but one of these cultures of *B. histolyticus* were fully virulent, producing typical lesions in guinea pigs, and all were associated with other aerobic and anaerobic species of bacteria. In one instance, *B. histolyticus* persisted until the twenty-fifth day, at which time the leg had to be amputated.

MacLennan¹ observed 1 case in which *B. histolyticus* was apparently the sole infecting organism. "The terminal picture was in every way similar to that produced in the thigh of a guinea pig experimentally, that is a rapid and extreme digestion and liquefaction of all the related soft tissues." Nothing of

the sort was apparently seen in Case 1 but we note that in 5 of MacLennan's cases of mixed infection where the appearance of the infected muscles was recorded, they were invariably described as being very dark in color—"dark red," "purple," or "black" and "of a very soft consistency" but, "digestion of tissues was apparently not observed."

LACERATIONS

There were 5 cases of lacerations from which *B. histolyticus* was recovered.

CASE 8.—A. E. (C. H.), a white man 21 years old, received a stab wound in the chest, penetrating the thoracic cavity. He came under treatment during the fourth hour after the injury. There was no evidence of gross contamination. He was given 3,000 units of tetanus antitoxin and 4,000 units of *B. perfringens* antitoxin. The wound was treated with sulfanilamide and sulfadiazine, and a total of 28 Gm. of sulfadiazine was given systemically during a week's stay in the hospital. Healing occurred without complications.

A culture made on admission yielded a nonhemolytic streptococcus, Group D, *M. albus*, *M. epidermidis*, an unidentified "hay bacillus," *B. tertius*, and *B. histolyticus*, apparently non-pathogenic on both subcutaneous and intramuscular injection of guinea pigs.

CASE 9.—W. G. (C. H.), a male Negro, 18 years old, received multiple stab wounds of the chest and abdomen, one penetrating the peritoneal cavity and the stomach. He came under treatment during the second hour after the injury. He was given 3,000 units of tetanus antitoxin and 4,000 units of *B. perfringens* antitoxin. A laparotomy was performed to repair the wound in the stomach and all incisions and wounds were completely closed without tension. Sulfanilamide was used locally and sulfadiazine systemically, a total of 53 Gm. in fifteen days.

On the fifth day the major stab wound was obviously infected and on the sixth day a kernel of corn (!) was extruded from it, showing that the débridement had been incomplete. From that time on healing was uneventful.

A culture from the débrided tissue showed a nonhemolytic streptococcus, Group D, *M. albus*, *M. epidermidis*, *M. candidus*, an unidentified "hay bacillus," and *B. histolyticus*, which failed twice to produce the characteristic lesions on subcutaneous inoculation into guinea pigs.

A culture taken on the fifth day showed *M. aureus*, *M. albus*, *Bact. aerogenes*, *Corynebacterium* sp. (?), and a nonhemolytic streptococcus.

A culture taken on the twelfth day showed *M. aureus*, *B. aerogenes*, and others not identified. If *B. histolyticus* was present in either of these later cultures it was not isolated.

CASE 10.—E. O'B. (M.G.), a white man 23 years old, received a severe laceration and avulsion of his left forearm in a warehouse accident, which exposed a strip of muscles about 8 cm. long. He was brought to the hospital within one hour. Treatment was started about three and one-half hours after the injury and consisted in the administration of 10,000 units of *B. perfringens* antitoxin and 10,000 units of *Bacillus septicus* antitoxin. No sulfonamide drugs were used. The area was grafted at once with split-thickness grafts taken from the thigh and sutured into place. Most of these grafts took satisfactorily, but certain areas which continued to granulate were treated with wet dressings. Complete healing occurred in about two and one-half months.

The débrided tissue yielded a nonhemolytic streptococcus, Group D, *M. aureus*, an unidentified "hay bacillus," *B. bifementans*, and *B. histolyticus*, which was fully virulent. Unfortunately, no further cultures were made.

CASE 11.—L. M. (C.H.), a Negro man 37 years old, received multiple stab wounds of the arm and chest in a street fight. He was treated within the first hour. The flexor tendon was severed and the radial artery was injured. Tetanus antitoxin, 3,000 units, were administered. He also received 500 c.c. whole blood. The flexor tendon and the radial artery were repaired and all wounds were closed without tension. No drugs were used locally but infection developed and sulfadiazine was given systemically from the ninth to the sixteenth day, a total of 25 Gm. The wounds were healed, however, in about twenty-two days.

A culture made from the arm at operation yielded *Streptococcus ignavus* (?), *M. epidermidis*, *M. candidus*, "hay bacillus," and *B. histolyticus* which was apparently only slightly pathogenic, producing moderate edema on subcutaneous injection of a guinea pig.

Cultures made from débrided tissue from the wounds in the chest yielded *B. bifermentans*, *B. sporogenes*, *Bact. aerogenes*, a micro-aerophilic alpha-hemolytic streptococcus, *M. candidus*, and *B. histolyticus* (fully virulent).

A culture taken from the arm on the ninth day showed *M. aureus*, a hemolytic streptococcus, *Bact. aerogenes*, *C. sp.* (?). One taken from the arm on the fifteenth day showed *M. aureus*, *M. aurantiacus*, *Bacillus cloacae*, *Bact. aerogenes*, *C. sp.* (?), *B. sporogenes*, a non-hemolytic streptococcus, and *B. bifermentans*. If *B. histolyticus* was present on the ninth and fifteenth day it was not recognized or isolated.

CASE 12.—S. C. (A.C.H.), a white woman, 63 years old, received a laceration of the lower part of the right leg and a fracture of the fibula in an automobile accident. She was treated during the first hour. The wound was grossly contaminated with dirt and clothing. It was débrided and left open. Sulfanilamide was used locally and sulfadiazine by mouth, 30 Gm. during a period of ten days. Healing was complete in six weeks without infection.

Cultures from the débrided tissues showed, among others not identified, a nonhemolytic streptococcus, *M. epidermidis*, a "hay bacillus," *Bact. aerogenes*, *Bacterium alkaligenes*, *B. perfringens*, *Bacillus putrificus*, *B. bifermentans*, *Bacillus cochlearius* (?), and *B. histolyticus* (fully virulent). No other cultures were made.

SUMMARY OF LACERATIONS

None of these cases ended fatally. Two wounds healed without infection, one healed after a minor infection, while two healed after serious infection. *B. histolyticus* was demonstrated only in the débrided tissues from these cases and there was never any clinical indication of its presence after the initial operations.

Three of these cultures were fully virulent; two were apparently nonvirulent.

GUNSHOT WOUNDS

There were three gunshot wounds.

CASE 13.—E. S. (D.G.H.), a white male, 18 years old, was accidentally shot by a hunting companion with a shotgun, in the sacrum, posterior pelvis, and gluteal regions. He was brought immediately to another hospital, where the wound was débrided but not completely, as subsequent x-rays showed that some of the shot had apparently entered the posterior pelvis. I was present and took some debris from the wound, including pieces of clothing and gun wads from all of which cultures were made.

The principal wound, about 7 inches long, running transversely across the sacrum, was closed with silk sutures, a Penrose drain protruding from each end of the wound. Prophylactic doses of gas gangrene antitoxin and tetanus antitoxin were administered but the amounts given are not available.

On the third day the patient was transferred to the Denver General Hospital. Aside from occasional pain in the region of the wound there were no complaints on the part of the patient. His general condition was good. There was no evidence of injury to the spinal cord, no loss of sensation, and all reflexes were satisfactory. X-rays showed "numerous metallic foreign bodies throughout both the gluteal regions with the largest concentration reaching into the sacrum."

The drain was removed on the ninth day after the wound was received. Recovery was uneventful. Smears from the débrided tissues showed numerous pus cells and a few clumps of gram-positive cocci. The cultures yielded "hay bacillus," *Streptococcus anginosus*, *Bacillus sphenoides*, *Bacillus subterminalis*, and *B. histolyticus*, the latter fully virulent.

CASE 14.—G. P. (C.H.), a white man 26 years old, was shot in the forearm, in the thigh, and in the head with a pistol. He was brought in for treatment within one hour. The skull was fractured but not penetrated by the bullet. He was given 500 c.c. of whole blood and the wounds were cleansed, débrided, and closed without tension. Sulfanilamide was used locally and sulfadiazine systemically. 37 Gm. in a period of eleven days.

There was no infection and healing was complete in ten days.

Cultures from the débrided tissue yielded a hemolytic streptococcus, a nonhemolytic streptococcus, Group D, *M. candidus*, *M. aurantiacus*, *M. epidermidis*, *Sarcina* sp. (?), *B. tertius*, and *B. histolyticus*. The latter was only moderately virulent for a guinea pig inoculated subcutaneously, producing edema and hematoma, but no break in the skin.

CASE 15.—K. B. (C.H.), a Negro man 31 years old, received multiple wounds from a pistol in the abdomen and chest during a fight in the street. Treatment was begun within one hour. The pleural cavities were not penetrated but the peritoneal cavity was, with damage to the mesentery. The mesentery and peritoneum were repaired and the wounds were closed without tension. Whole blood, 250 c.c., were transfused. No antitoxin was given but sulfadiazine was administered systemically, 70 Gm. in nineteen days.

About the twentieth day an abscess developed at the point of exit of the bullet in the lumbar region. This was deeply incised and drained on the twenty-sixth day, after which complete healing occurred, the patient being discharged on the forty-fifth day.

A culture from the débrided tissues showed *M. albus*, *M. varians*, *M. epidermidis*, *B. tertius*, and *B. histolyticus*. A culture taken from the abscess on the twentieth day yielded *M. aureus*, a nonhemolytic streptococcus, and *B. histolyticus*. One taken on the twenty-fifth day yielded *M. aureus*, a nonhemolytic streptococcus, *B. coli*, and *B. histolyticus*. The thirty-seventh day showed the same species plus an unidentified species of *Corynebacterium*. *B. histolyticus* was still present. Of the four cultures of *B. histolyticus* recovered, we had an opportunity to recheck only the first, that is, the one from the débrided tissues, which was fully virulent.

SUMMARY OF GUNSHOT WOUNDS

All of these patients recovered, 2 without infection, 1 after the development of a deep abscess. In 2 of these cases *B. histolyticus* was recovered only from the débrided tissues; in Case 15 it was recovered not only from the débrided tissues but also from cultures taken on the twenty-fifth and thirty-seventh days.

Two of these cultures of *B. histolyticus* were fully virulent, one was only moderately so.

BURNS

B. histolyticus was found in two cases of burns.

CASE 16.—A. S. (C.H.), a white man, 52 years old, received first, second, and third degree burns on the chest, neck, back, and shoulders in an explosion of kerosene. About 25 per cent of the surface of the body was burned but less than 5 per cent was regarded as third degree.

This patient was not received in the hospital until after two or three days had elapsed. At that time there was evidence of gross contamination with ants and maggots crawling over the burned area.

These were thoroughly cleansed and covered with pressure dressings soaked in merthiolate. Saline solution tub baths were given at frequent intervals. Medication included 1,700 c.c. of plasma, 500 c.c. of blood, and 25 Gm. of sulfathiazole systemically in ten days. The patient was discharged in sixty-five days but the time of complete healing was not recorded.

Cultures from the débrided tissues showed a hemolytic streptococcus, a nonhemolytic streptococcus, Group D, *M. epidermidis*, an unidentified gram-negative rod, *B. perfringens* and *B. histolyticus* (fully virulent).

A culture taken on the eleventh day showed a hemolytic streptococcus, *M. aureus*, *B. coli*, *Micrococcus luteus*, *M. aurantiacus*, *S. sp.* (?) and *C. sp.* (?). One taken on the twenty-sixth day showed a hemolytic streptococcus, *M. aureus*, and *M. epidermidis*.

CASE 17.—R. D. (C.H.), a white male, aged 4 years, was scalded by hot water on the chest and arms. He was brought in for treatment during the third hour after the injury, which was regarded as third degree but involving only 5 to 9 per cent of the surface area. He was given 1,500 units of tetanus antitoxin before admission and 3,000 units more afterward. He was treated with saline solution pressure dressings. No sulfonamides were used. Healing was uneventful and complete in thirteen days' time.

The débrided tissues showed *M. epidermidis*, *M. candidus*, an unidentified gram-negative rod, and *B. histolyticus* (moderately virulent).

SUMMARY ON BURNS

Both patients recovered, one without signs of infection, one after a severe infection. *B. histolyticus* was recovered from the débrided tissues of both pa-

tients but was not recovered from subsequent cultures and there was never any clinical evidence of its presence. One of the cultures was fully virulent, one only moderately so.

These are believed to be the first cases of burns in which *B. histolyticus* has been isolated.

GENERAL DISCUSSION

The occurrence of *B. histolyticus* in accidental wounds, as presented here, is regarded simply as an expression of the widespread occurrence of this organism in nature. It should be distinctly understood that the débrided tissues were minutely studied in these cases as a means of determining the potential pathogenic agents; we do not advocate such cultures routinely since it is quite apparent that they have little or no relation to the subsequent development of infections if surgical treatment is instituted within a reasonable period of time.

Ever since the discovery of *B. histolyticus* as one of the pathogenic factors in gangrenous wounds by Weinberg and Sequin,⁴ in 1916, and their demonstration of its remarkable and peculiar pathogenic properties in experimental animals, there has been much speculation and discussion as to its actual role in accidental infections. Weinberg and Sequin recovered it in 8 out of 30 gangrenous wounds before describing it; they recognized that these cases were exceptionally severe as 4 were fatal and the other 4 required amputations. They later⁵ emphasized that the rapid liquefaction of tissues produced by the toxin of this organism was unusually favorable to the synergic growth of other anaerobic bacteria such as *B. perfringens* and *B. edematiens* (*Bacillus novyi*). Legros⁶ was apparently the first to describe a human case in which the lesions were similar to those in animals; this was a mixed infection with cocci, *B. edematiens* and *B. sporogenes*.

Pure infections are indeed exceptional, as Combiesco⁷ pointed out. Weinberg saw only one, which required immediate amputation, and I have seen no records of others prior to those of MacLennan.¹ It seems probable, therefore, that the characteristic lesions as seen in experimental animals and in a few rare accidental pure infections are masked and modified in the usual mixed infections in gaseous gangrene to such an extent that they can seldom be recognized. But there is no doubt, on the other hand, that a virulent *B. histolyticus* may play a profoundly important role when it occurs in a mixed infection.

B. histolyticus is a common organism in nature and has a widespread distribution. I recovered it from human feces in 1923⁸ Although Kahn⁹ failed to recover it in a large series of stool examinations, Torrey^{10, 11} isolated it from the ileocecal region of two patients who had colectomies, and Weinberg, Renard, and Davesne¹² found it in two gangrenous appendices. It probably occurs not uncommonly in the intestinal tracts of man and animals from which it readily finds its way into the soil.

Peterson and I¹³ obtained it from arable soil in California, Chiari¹⁴ from soil and tannery wastes in Germany. Whitehead and I¹⁵ also obtained several strains from African poisoned arrows pasted with a mixture of poisonous plant juices in clay.

Although Weinberg and Sequin regarded *B. histolyticus* as an obligate anaerobe, I showed, in 1923,¹⁶ that it was a facultative aerobe; I believe that it can be isolated more easily by aerobic than by anaerobic methods, but its colonies are minute and are likely to be overlooked in a mixed culture by all but the best trained and most meticulous bacteriologists. This accounts for the fact that it was not discovered until 1916 and that it is seldom reported even today. Thus,

in the present study of 2,493 contaminated civil wounds by 9 cooperating hospitals, only 3 submitted cultures containing *B. histolyticus*. It seems significant that of 15 cultures from these 3 hospitals in which we found *B. histolyticus*, 11 came from a single hospital, 7 of these being pure and already identified correctly, while 1 was pure but had not been identified; 2 were impure but were suspected to contain *B. histolyticus*, and 1 was pure but had been tentatively identified as an unknown species of "alkaligenes."

Another hospital submitted 3 cultures, 1 pure and identified, 1 impure with suspected *B. histolyticus*, and 1 pure but not identified. Still another hospital submitted a single culture, impure and unidentified.

SUMMARY

B. histolyticus was demonstrated in cultures taken from débrided tissues in 17 civil wounds. There were 7 compound fractures, 5 lacerations, 3 gunshot wounds, and 2 burns. These are believed to be the first records of *B. histolyticus* in connection with burns.

Only 1 case, that of a compound fracture, proved fatal. This was a typical case of gaseous gangrene caused by *B. perfringens* and other bacteria. The typical lesions produced by pure infections of *B. histolyticus* were probably masked and were not recognized.

All of the other patients recovered and the peculiar lesions of infection by *B. histolyticus* were not recognized in any case.

Persistence of *B. histolyticus* in an infected wound was noted in one case of compound fracture of the leg as late as the twenty-fifth day, when the leg had to be amputated. Persistence to the thirty-seventh day was observed also in a case of multiple pistol shot wounds.

The occurrence of *B. histolyticus* in wounds is regarded solely as an expression of its widespread occurrence in nature. If wounds are promptly and adequately débrided it rarely persists. If gaseous gangrene develops, the peculiar lesions produced by this organism in pure infections are likely to be masked and overlooked. It may persist in a mixed infection for twenty-five to thirty-seven days without giving any clinical indication of its presence.

The comparatively infrequent demonstration of this organism in accidental wounds probably gives an erroneous conception of the actual frequency of its occurrence owing to the fact that it is so easily overlooked in a bacteriologic examination of a mixed infection.

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THE OCCURRENCE AND POSSIBLE SIGNIFICANCE OF BACILLUS TETANI IN COMPOUND FRACTURES, LACERATIONS, GUNSHOT WOUNDS, AND BURNS

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THE writing of this paper was suggested by the fact that out of a total of 2,493 civil contaminated wounds studied under the Contaminated Wound Project, there were 11 in which *Bacillus tetani* was recovered from the débrided tissues. None of these patients developed tetanus while in the hospital and none is known to have done so since, although contact with some of the patients has been lost. These 11 cases were located in four hospitals, as follows:

Charity Hospital, New Orleans, La.	2 cases
Detroit Receiving Hospital, Detroit, Mich.	6 cases
Massachusetts General Hospital, Boston, Mass.	1 case
Cincinnati General Hospital, Cincinnati, Ohio	2 cases

One patient, treated in Charity Hospital for a burn, failed to yield *B. tetani* from the débrided tissue but after a transfer to another hospital on the thirty-second day was reported to have developed tetanus on the thirty-fifth day, from which he eventually recovered.

COMPOUND FRACTURES

There were 5 compound fractures, 1 of which was complicated by a gunshot wound.

CASE 1.—J. G. (C. G. H.), a Negro man 33 years old, July 19, 1942, received a compound fracture of the proximal phalanx of the left fifth finger and a pistol wound in the shoulder. He was admitted to the hospital within one hour, and operated upon during the third hour after the injury was received. He received a prophylactic dose of tetanus anti-

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toxin. A portion of the bone of the finger was removed and an aluminum splint was applied. Débridement of the gunshot wound was regarded as somewhat incomplete and unsatisfactory. Sulfanilamide was applied locally and 23 Gm. of sulfadiazine were given orally during a period of nine days. No serious infection occurred at this time.

The débrided tissues showed *Micrococcus aureus*, *Streptococcus viridans*, *Bacillus aerogenes*, *Bacillus perfringens*, and *B. tetani*.

This patient was seen last Aug. 17, 1942, at which time the wound was well healed superficially but there was still some local edema and induration and little function of the proximal interphalangeal joint. An attempt in August, 1944, to ascertain the subsequent history of this patient failed.

CASE 2.—M. B. (M. G. H.), a white man 20 years old, Sept. 13, 1942, suffered a compound fracture of the right radius and ulna, a compound fracture of the lower part of the right leg, and a laceration of the forehead in an accident in a railroad yard. He was hospitalized within one hour in fair condition but with impending shock. Operation was started during the next hour. The wounds were contaminated by cinders. It was considered necessary to amputate both the arm and leg above the sites of fracture. The stumps were dusted with sulfanilamide and closed, the arm without tension, the leg with tension. The laceration on the forehead was also débrided and completely closed. Sulfadiazine was administered systemically, a total of 47 Gm. in thirteen days.

The débrided tissues showed several species of bacteria, among which were identified *Bacterium coli*, *Bacterium proteus*, *B. tetani*, and *Bacillus histolyticus*, the two latter fully virulent.

The wounds in the head and arm healed in twenty-four days without any clinical evidence of infection except a slight serous discharge in the arm.

On the twelfth day there was still some purulent exudate in the leg and *M. aureus*, *Micrococcus albus*, *Bact. coli*, and *Bact. proteus* were found in a culture taken on that day but on the twenty-fourth day all clinical signs of infection had disappeared. However, the patient remained in the hospital for sixty-five days, when he was discharged using a wooden leg. Up to Sept. 12, 1944, he had not developed tetanus.

CASE 3.—E. C. (C. H.), a Negro man 24 years old, Jan. 8, 1943, was struck by an automobile and sustained a compound fracture of the left radius. He was admitted to the hospital within one hour and received 3,000 units of tetanus antitoxin and 4,000 units of *B. perfringens* antitoxin. The wound was débrided during the third hour; the fracture was reduced and the defect closed with cotton sutures without tension. The arm was fixed in plaster. No drug was used locally in the wound but 22 Gm. of sulfadiazine and sulfathiazole were administered orally during the first four days during which the patient's progress was uneventful, and after which he was transferred to another hospital where the fracture healed without infection. May 10, 1943, there was only a slight stiffness of the wrist joint. Sept. 5, 1944, he was reported as not having had tetanus.

Cultures made from the débrided tissues yielded *Micrococcus epidermidis*, *Bact. coli*, *Bacterium cloacae*, *Bacterium alkaligenes*, *Bacillus tertius*, and *B. tetani*.

CASE 4.—J. T. (D. R. H.), a Negro man 54 years old, Feb. 20, 1943, was struck by an automobile and sustained a compound fracture of the lower third of the tibia and fibula of the left leg in a city street. He was admitted to the hospital within one hour and given 1,500 units of tetanus antitoxin but the operation was deferred to the sixth hour owing to congestion in the operating rooms at the time.

The laceration was about three inches in length, through which approximately three inches of tibia protruded. The wound and exposed bone were very dirty. All of the lacerated muscles and exposed and contaminated tissues were completely débrided. The wound was irrigated briefly but thoroughly with physiologic saline solution from the depths outward; the fracture was reduced and the skin closed over it with silk sutures after which a plaster cast with three Steinmann pins was applied.

No drug was used locally but 37 Gm. of sulfadiazine were given during his thirty-two days in the hospital. When the cast was removed after seventy-five days the wound was found to be completely healed.

The débrided tissues yielded a nonhemolytic streptococcus, *M. epidermidis*, *Micrococcus tetragenus*, *B. perfringens*, an unidentified nonpathogenic bacillus, and *B. tetani*.

He was last seen about one year later and had not developed tetanus.

CASE 5.—G. Z. (C. H.), a white male, 10 years old, July 14, 1943, fell in a field and suffered a compound fracture of the radius and a simple fracture of ulna. Dirt was forced into the wound. He wrapped a rag around the wound and went home. An ambulance was called, at which time the fracture was reduced, the wound covered with sterile gauze, and an aluminum splint applied. He was given sulfanilamide locally and systemically but no antitoxin.

On the second day the wound became infected and he was brought to the hospital where evidence was found of incipient gaseous gangrene. The wound was then thoroughly débrided for the first time. The wound was packed with sulfanilamide, sulfadiazine, and methylene blue powdered together and he was also given 30,000 units of tetanus antitoxin, 60,000 units of *B. perfringens* antitoxin and 1,250 c.c. of whole blood. He also received 12 Gm. of sulfadiazine systemically. Response was slow but the wound was completely healed in about sixty days.

The débrided tissues yielded nonhemolytic streptococci, *B. perfringens*, *B. tertius*, *Bacillus bifermentans*, *Bacillus capitovalis*, a "hay bacillus," *B. coli*, and *B. tetani*. We rechecked three separate cultures of this strain of *B. tetani*. A culture taken on the third day showed hemolytic and nonhemolytic streptococci, *B. bifermentans*, *Bacillus sporogenes*, *B. tertius*, *Bact. coli*, *Bact. proteus*, and *Bact. cloacae*. *B. perfringens* and *B. tetani* were not recovered. A culture taken on the eleventh day showed hemolytic streptococci, *Bact. coli*, *B. aerogenes*, *B. bifermentans*, *B. sporogenes*, and *B. perfringens*. Again *B. tetani* was not recovered.

This patient was reported Sept. 5, 1944, as free from tetanus up to that date.

LACERATIONS

There were 5 lacerations.

CASE 6.—R. H. (D. R. H.), a negro woman, 25 years old, June 7, 1942, cut the back of her right wrist, severing the extensor tendons of the third, fourth, and fifth fingers and the extensor carpi ulnaris. She was admitted to the hospital during the first hour and received no antitoxin nor drugs. Under brachial block anesthesia, the area around the wound was washed with soapy water, completely débrided, and irrigated with 4 liters of sterile physiologic saline solution. The tendons were reunited with silk and catgut ligatures and the wound was closed under slight tension. The hand was dressed in extension using a plaster mold. Healing occurred in twelve days and function has been excellent.

The débrided cultures yielded *Micrococcus varians*, *Micrococcus candidus*, *M. epidermidis*, an unidentified species of *Corynebacterium*, *B. capitovalis*, and *B. tetani*. We rechecked two separate cultures of this strain of *B. tetani*.

She was last seen about one year later and had not developed tetanus.

CASE 7.—M. V. (C. G. H.), a Negro woman 26 years old, June 12, 1942, cut her right thumb with a piece of glass, resulting in a division of the extensor pollicis longus tendon. It was wrapped in a "clean" cloth as a first-aid dressing. She was admitted to the hospital during the third hour and operated upon during the sixth hour after the injury was received. A prophylactic dose of tetanus antitoxin was given. The laceration was débrided and the tendon repaired. The wound was dusted with sulfanilamide and closed with silk ligatures. She also received 16½ Gm. of sulfadiazine systemically during a period of seven days in which healing occurred without evidence of infection.

The débrided tissues yielded *M. aureus* (?), *B. capitovalis*, and *B. tetani*.

This patient was seen for the last time June 25, 1942. The wound had healed well and function of the thumb appeared to be good. She did not keep a later appointment and an attempt in August, 1944, to ascertain her subsequent history failed.

CASE 8.—J. C. (D. R. H.) a Negro man 35 years old, Aug. 2, 1942, in a fight received multiple lacerations, one 15 inches long, of the left thigh with partial severance of the vastus lateralis, tensor fasciae latae, and semimembranosus as well as several stab wounds in the neck, shoulder, and abdomen.

He was admitted to the hospital within the first hour and operated upon during the fifth hour after the injury was received.

A prophylactic dose of 1,500 units of tetanus antitoxin was given but no sulfonamide drugs were used. The wound was thoroughly washed with soapy water, completely débrided, and irrigated with large amounts of sterile physiologic saline solution. The layers were closed with silk, the skin with heavy catgut, under considerable tension.

The débrided tissues yielded *M. epidermidis*, a "hay bacillus," *Bacterium pyocyaneum*, and *B. tetani*.

Stitch abscesses developed in the major wound causing a separation of the skin and delaying healing but this infection was easily controlled by saline solution compresses and the wounds were all completely healed in twenty-three days. Cultures taken on the ninth day showed *Micrococcus aurantiacus*, *Micrococcus albus*, and *Str. viridans*.

He was last seen about one year later and had not developed tetanus.

CASE 9.—E. B. (D. R. II.), a Negro man 36 years old, in a fight on Sept. 7, 1942, in a beer hall, received a laceration twenty-three inches long extending almost from spine to sternum, along the upper left side of the chest wall level with the nipple, cutting through the latissimus dorsi and down to the scapula at one point. He was admitted to the hospital within the first hour, suffering from bronchitis and acute alcoholism, and was operated upon during the fourth hour after the injury was received. The wound was apparently not grossly contaminated and no serums or sulfonamides were used.

The wound was only lightly débrided, irrigated with physiologic saline solution, and closed in layers with silk sutures, not without some tension.

The débrided tissues yielded *Str. viridans*, *Streptococcus fecalis*, *M. epidermidis*, an unidentified species of anaerobic coccus, *B. sporogenes*, and *B. tetani*.

Owing perhaps to insufficient pressure on the dressing, a large hematoma developed in the dorsal end of the wound. Infection developed in this hematoma on the sixth day, with fever, swelling, and induration but no cultures were made at that time. In spite of this infection, the patient was well enough to be released from the hospital on the twelfth day. He returned to the clinic on the twenty-second day, at which time a culture showed *M. varians* and unidentified diphtheroids. Anaerobic cultures gave negative results. The wounds were all completely healed on the thirtieth day. He was last seen about two months later and had not developed tetanus.

CASE 10.—P. R. (D. R. H.), a Negro woman 43 years old, Nov. 20, 1942, was severely bitten by a dog on the left ankle and thigh, and also sustained a fracture of the left ring finger. She was admitted to the hospital within one hour, and operated upon during the third hour after the injury occurred. She received no antitoxin. The major bitten area was thoroughly washed with soapy water and completely excised, well irrigated with physiologic saline solution and covered with a split-thickness skin graft fastened with silk sutures; the minor puncture wounds were left open under petrolatum gauze dressings; 37 Gm. of sulfadiazine were administered orally during a period of ten days. Healing occurred without complications; the dressings were removed on the eighth day.

The débrided tissues yielded *Micrococcus citreus*, "hay bacilli," *B. perfringens*, and *B. tetani*.

She was last seen about one year later and had not developed tetanus.

BURNS

There were only 2 burns.

CASE 11.—F. P. (D. R.), a 73-year-old white man, slightly diabetic, on May 14, 1942, sustained second degree burns of the face and left elbow while trying to extinguish a fire in a barn. He was admitted to the hospital within one hour and operated upon during the second hour after the accident. The burned skin was washed with soapy water and was débrided. The arm was treated with Dymixal, a proprietary jelly containing crystal violet, brilliant green, and acriflavine. The face was treated with Dodecol, which contained 5 per cent sulfadiazine and 5 per cent sulfanilamide. These treatments were repeated daily for twelve days.

The débrided tissues yielded a nonhemolytic streptococcus, *M. varians*, *M. aureus*, *Micrococcus luteus*, *M. candidus*, *Corynebacterium* sp. (?), and *B. tetani*.

The burns on the face were healed by the fifteenth day; healing of the arm somewhat delayed by a slight infection but was complete by the twentieth day. The exact character of this infection was not determined.

He was still in good health after three months.

CASE 12.—R. J. (C. H.), a Negro man 24 years old, Aug. 3, 1942, sustained second and third degree burns of the lower legs and feet, first and second degree burns of the right arm and chest, lacerations of the face and hands, and a simple fracture of one arm during an

explosion of gasoline. He was admitted to the hospital within the first hour and operated upon during the sixth hour, having already received 3,000 units of tetanus antitoxin; he was also given two infusions of plasma, totaling 550 c.c. and four transfusions of whole blood, totaling 2,000 c.c.

No sulfonamide drugs were used up to this time. The burns were débrided and treated with saline pressure dressings. The fracture was reduced and splinted. Sulfadiazine, 41 Gm., were given orally during the first ten days.

The débrided tissues yielded *M. candidus*, *M. epidermidis*, "hay bacilli," *B. perfringens*, *B. bifementans*, and *B. tertius*.

Upon changing the dressings on the left leg on the sixteenth day a gangrenous condition was discovered which required the amputation of that leg.

Cultures taken at that time yielded nonhemolytic streptococci, *M. aureus*, *M. albus*, *M. candidus*, *M. aurantiacus*, *M. epidermidis*, "diphtheroids," *B. bifementans*, *B. tertius*, and *B. sporogenes* and several unidentified gram-negative rods.

On the twenty-third day a culture from the stump yielded all of these except *M. aurantiacus*, *M. albus*, *B. bifementans*, and *B. tertius*, and in addition showed hemolytic streptococci to be present.

The patient was transferred to another hospital on the thirty-second day and three days later was reported to be suffering from tetanus. Sept. 5, 1944, he was reported as having recovered but details of his attack could not be obtained.

SUMMARY OF CASE HISTORIES

Summarizing these cases we note that there were 5 of compound fractures, 5 of lacerations, and 1 burn from débrided tissues of which *B. tetani* was recovered along with other bacteria of considerable variety. None of these developed tetanus.

In the case of one other burn, tetanus developed on the thirty-fifth day, three days after the patient's release from the hospital in which treatment was initiated. *B. tetani* was not recovered from the débrided tissues in this case.

DISCUSSION AND HISTORICAL SURVEY

There are two schools of thought with reference to the value of bacteriologic examinations of tissues surgically débrided from wounds. The first holds that cultures should always be made from such tissues in order to ascertain the potential infectors. As Pulaski, Meleney, and Spaeth¹ have pointed out, accidental wounds are always contaminated and no one can tell which wound is going to develop infection. "The knowledge of the bacterial flora in any given contaminated wound gives a sound basis for the rational prophylactic treatment to prevent infection in that wound."

The second school holds that cultures from débrided tissues can rarely yield any information of real practical value in time for the surgeon to utilize it, no matter how interesting it may be from an academic viewpoint. Those who belong to the second school believe that time and work involved are rarely justified unless, and until, clinical and microscopic evidence shows that infection has already started, in which case surgical decisions should be based primarily upon clinical and microscopic examinations which do not involve the loss of time required for the incubation of cultures. In these cases cultures may be made as a check upon the microscopic examination and to increase our knowledge, knowing that the findings can only rarely, if ever, influence surgical procedures except in a general way.

The very common occurrence of coagulase-positive staphylococcic infections, of hemolytic streptococci without streptococcal infections, of *B. perfringens* without gaseous gangrene, and the occasional occurrence of *B. histolyticus*² and other pathogens without specific infections illustrate this point of view.

On the other hand, the occurrence of *B. tetani* in wounds and the occasional delayed development of tetanus after primary healing when the passive immunity conferred by the routine administration of tetanus antitoxin has disappeared, suggest that it may be quite worth while to examine débrided tissues especially for this organism in order that suitable precautions may be taken, such as active immunization with tetanus toxoid or re-immunization with serum in the event of a new surgical emergency. There is a great difference in the cost of examining débrided tissues for *B. tetani* by such simple procedures as those outlined by Gilles^{3,4} and the complicated technique required for a complete aerobic and anaerobic examination.

CLINICAL CASES OF DELAYED TETANUS

The problem of delayed or idiopathic tetanus is quite old. According to Burnett,⁵ Pescay, many years ago, observed a number of cases of generalized tetanus developing without obvious immediate causes in men who had marched the preceding day in a blazing sun in Spain, and Larey, in the Austrian campaign of 1809, attributed 110 cases of tetanus in a single day in wounded soldiers to the fact that the battle of Bautzen, in which they fought on an extremely hot day, was followed by a cold damp night. Sédillot also attributed an excessive incidence of tetanus after the battle of Constantine in 1836, to a similar situation.

In more recent times there have been many examples of men wounded in battle, apparently successfully treated prophylactically with tetanus antitoxin, by débridement, and by successful fixation of fractures, with complete or nearly complete healing, only to succumb to tetanus upon undue exertion, massage of old scars, exposure to sun, inoculation with quinine, or new surgical emergencies without the protection that might have been afforded by re-immunization with antitoxin or tetanus toxoid.

Courmont and Cordier,⁶ in 1910, recorded two separate attacks of tetanus in the same subject, a gardener who developed general subacute tetanus following a puncture wound in the foot. This attack subsided after intensive treatment with tetanus antitoxin. Five years later the gardener fell, injuring his nose. This wound healed superficially but eleven days later tetanus again developed. This attack was also cured by antitoxin although not without a severe bout with serum-sickness.

Naturally, in this and other similar cases, the question arises whether the second attack was due to tetanus bacilli lying dormant in the old wound re-activated by the new injury or a totally new infection. The fact that the second attack in this case was of the cephalic type suggests the latter alternative.

Gubb and Duvernay,⁷ in 1915, recorded a case, without any record of cultures, in which a period of seventy-seven days elapsed from injury until onset of symptoms, resulting fatally one week later.

Penhallow,⁸ in 1916, recorded a case in a soldier precipitated by a new operation two months after receipt of his wound. This man recovered under intensive treatment with antitoxin.

Barling⁹ had 3 patients with delayed tetanus under observation at one time. In one, tetanus occurred after fifty-one days, in another after fifty-three days, and in a third after forty days. All recovered from tetanus but the last died from a streptococcal gangrene which developed after seventy-three days.

Miller¹⁰ had a patient who developed slight tetanus at seven days, from which the soldier apparently recovered but the attacks recurred on the seventy-

fourth day along with a bronchopneumonia, probably induced by chronic alcoholism, and ended fatally on the eighth day in spite of 9,000 units of tetanus antitoxin.

Doberer¹¹ recorded a case of delayed tetanus in a soldier 128 days after the wound was received, while Foster¹² had 3 cases of gunshot wounds, all promptly treated prophylactically with tetanus antitoxin, one occurring spontaneously at eighty-six days, one after a fall at 106 days, and the last after a fall followed by bronchopneumonia at 146 days.

Vernoni¹³ reported 4 patients with tetanus with delayed or recurrent symptoms after intervals of fifty days in one, seventy days in two, and covering ten months in a fourth, precipitated by excessive exercise in 2 cases, massage of an old wound containing a foreign body in 1, and undue exposure to the sun in a fourth case. All eventually recovered.

Other cases of late tetanus were recorded in 1917 by Kaposi,¹⁴ of recurrent tetanus by Westwater,¹⁵ and of local tetanus as modified by the prophylactic use of tetanus antitoxin by Burrows.¹⁶ However, in view of the record we can scarcely agree with Burrows that local tetanus is a new form of disease.

For long-term records we may cite a case by Brunzel¹⁷ after six years. Brunzel's title says "*sieben Jahre*" but why exaggerate? The patient had been slightly wounded in the arm by a bursting grenade in 1915. The wound appeared at first to be healing but a little later an abscess developed from which a small piece of metal was removed. Moderate trismus and pain in the neck occurred at the time. No reference was made to cultures or use of antitoxin but the patient recovered, only to succumb to tetanus in 1921 in spite of intensive treatment with antitoxin.

Ernst,¹⁸ in 1931, observed symptoms of tetanus six days after opening a small abscess in the scar of a wound fourteen years old. This patient recovered after heavy doses of antitoxin. There was no record of bacteriologic examinations. Bonney, Box, and MacLennan¹⁹ recorded the case of a young unmarried woman who in 1928 underwent an operation for the removal of uterine fibroid tumors. Fifteen days later symptoms of tetanus developed but she recovered under treatment. *B. tetani* was not demonstrated in the discharges at that time. In 1938, ten years later, a new crop of fibroid tumors developed. She was given tetanus antitoxin and again operated upon. *B. tetani*, type III was recovered from the scar tissues. She recovered from the operation and did not develop tetanus again. Serum was negative for H and O agglutinins for her own culture and eight other antigenic types of *B. tetani*.

EXPERIMENTS ON DELAYED TETANUS

The experimental basis for our modern understanding of delayed tetanus was laid many years ago when Vaillard and Vincent²⁰ first showed, in 1891, that cultures of *B. tetani* grown at 20-22° C. were relatively nontoxic, that cultures grown at 37° C. and detoxified by heating at 65° C. for twenty minutes or by repeated washing could be injected into guinea pigs and rabbits without producing tetanus, that such organisms are phagocytized, both in vitro and in vivo, and that they may be reactivated by injections of lactic acid, trimethylamine, "*Microbacillus prodigiosus*," and other bacteria, with the production of typical symptoms of tetanus ending in death. Although Sanchez-Tolledo²¹ was unable to confirm these observations which led to an amusing polemic with Vaillard,²² the essential facts have been rechecked by many observers. It seems probable that Sanchez-Tolledo actually had impure cultures although he claimed that they were pure; Vaillard and Rouget²³ also showed, in 1892, that repeated changes

are necessary to remove all toxin by washing and that excessive doses of either washed or heated cultures are likely to cause such experiments to fail.

Vincent,²⁴ in 1904, observed a case of so-called "idiopathic" or "spontaneous" tetanus in a man who took a walk in the sun on a hot day, in whom no site of infection could be determined. Following this, he was able to show that although frogs were insusceptible to tetanus at ordinary temperatures, they succumbed at 25 to 30° C. and that dogs, rabbits, and guinea pigs inoculated with detoxified spores of *B. tetani* succumbed to tetanus under the influence of insolation, exposure to temperatures of 38 to 42° C., or injections of quinine, in some cases after thirty, forty, or even sixty days. Often, *B. tetani* could be demonstrated at the site of inoculation of the quinine, indicating that the bacilli which had been phagocyted had not been killed and were probably transported by the mobile phagocytes to the site of the necrosis induced by the quinine. They were also found in the livers, spleens, bone marrows, and blood.

Tarrozi²⁵ showed that detoxified tetanus bacilli injected into rabbits could be reactivated by local injuries up to three and one-half months and could be recovered after death from the livers, spleens, kidneys, lungs, and bone marrows. Canfora²⁶ observed that during the first few days after subcutaneous or intravenous inoculation of rabbits with detoxified tetanus spores, the slightest wound would provoke an attack of tetanus and confirmed the presence of *B. tetani* in the livers, spleens, lungs, kidneys, and lymph glands, but the blood usually remained sterile.

Reinhardt and Assim²⁷ proved that these observations on animals were also applicable to man in 4 cases in which they recovered *B. tetani* from the livers, lungs, spleens, and in some instances from the kidneys, blood, and lymph glands.

The practical importance and relation of hypodermic injections of quinine to tetanus were studied by Semple,²⁸ Francis,²⁹ Browning,³⁰ Koser and McClelland,³¹ and Teale and Bach³² just prior to, during, and immediately after, World War I. What a fortunate thing it is in World War II, with fighting in the tropics causing the excessive exposure of our troops to heat and sun, the great hazard of malaria, and the consequent necessity of injections of quinine, that our soldiers have the protection afforded by active immunization with tetanus toxoid!

THE OCCURRENCE OF *B. TETANI* IN WOUNDS

With our modern understanding of the spreading habit of *B. tetani* upon solid media, in which *B. tetani* is as unique among the anaerobic bacteria as *Bact. proteus* is among the aerobes, we now consider that *B. tetani* is the easiest anaerobe to isolate in pure culture. Yet it has not always been so. When isolation was attempted from deep agar, pure cultures were particularly hard to secure. These difficulties were emphasized by Frothingham,³³ in 1894, and have been experienced by many investigators since then.

Probably the first instance in which *B. tetani* was recovered from a wound not resulting in tetanus was recorded by Bain,³⁴ in 1903. This was the case of a girl, 13 years old, who on July 3, 1902, sustained a wound in the hand from a blank cartridge. The wound was excised within fifty-five minutes at Massachusetts General Hospital in Boston. The child received no tetanus antitoxin but the wound healed promptly and she remained well. The debrided tissues, together with wadding and burnt powder grains, were sent to the bacteriologic laboratory where a culture of *B. tetani* was recovered from an unspecified mixture of organisms. Since no fermentation tests except milk were recorded,

we cannot be sure that this culture was pure but it was morphologically characteristic and produced tetanus in mice and guinea pigs. Bain emphasized that "this case should furnish a strong argument in favor of the early and complete incision of all wounds which from clinical experience are likely to be followed by tetanus."

Robertson,³⁵ studying the occurrence of *B. tetani* in war wounds, in 1917, made no attempt to isolate pure cultures, but organisms morphologically resembling *B. tetani* were found in 64 out of 252 wounds not developing tetanus. Of these, 60 cultures were tested on mice; only 9 produced tetanus. As a control upon these observations, specimens of pus from 45 cases of tetanus were studied. Eight of these failed to grow anaerobically, while of 37 showing anaerobic growth, only 29 showed organisms morphologically resembling *B. tetani*, and of 23 cultures tested for toxicity only 12 produced tetanus.

Weinberg and Séguin³⁶ in the same year recorded that in spite of prophylactic inoculations of all wounded men with tetanus antitoxin, *B. tetani* could be recovered from 9 per cent of them. As Sanford³⁷ said in 1918, "Tetanus is the black beast that lurks in the shadows for the convalescent wounded soldiers. The maelstrom of the battlefield may be safely passed; the soldier rejoices in having received only a slight shell wound, and is invalided home for a few weeks, but terrible indeed may be the end if that bit of shell has carried with it the spores of the anaerobic tetanus bacillus."

Harde³⁸ encountered *B. tetani* in two wounded men, neither of whom developed tetanus. Upon deciding to look for it routinely he found that he was unable to demonstrate it in 30 cases either by direct inoculation of mice or by microscopic examination and animal inoculations of mixed cultures. These methods failed in his hands even with frank cases of tetanus. The examination of 60 shell fragments extracted from wounds also gave negative results except in one instance.

It was Wilson and Steer,³⁹ who, in 1918, discovered that "*B. tetani* grows out from the main mass of the mixed growth as a very fine film with woolly margins," from which pure cultures could generally be picked on first trial. They recovered several pure cultures directly from wounds in this manner.

Adamson⁴⁰ also experienced great difficulty at first in demonstrating *B. tetani* in wounds and even failed in 9 instances of frank tetanus but later utilized the spreading characteristic successfully. Although Tulloch⁴¹ did not emphasize this point he was probably quite familiar with it for he was able to demonstrate *B. tetani* in 21 out of 100 chronic wounds, as follows:

7 to 30 days	8 cases
32 to 64 days	5 cases
100 to 138 days	4 cases
305 days	1 case
733 to 882 days	3 cases

Finally, Fildes⁴² exploited the spreading habit of *B. tetani* to isolate 75 new strains, among which were 6 strains from 6 cases of tetanus, following which we record a hiatus of fifteen years without further significant contributions in this field.

TETANUS IN WORLD WAR II

With the beginning of World War II the problem of tetanus rose again and in 1940. Ratheke⁴³ recorded the demonstration of *B. tetani* in 6 out of 140

wounds which he studied and emphasized again the necessity of using tetanus antitoxin routinely as a prophylactic in all wounded men.

But the conditions of this war are different from those of World War I in two important respects. First, most of the soldiers have been actively immunized with tetanus toxoid. Second, the local and systemic use of sulfonamide drugs has been widespread among wounded soldiers.

In France, where tetanus "anatoxin" or toxoid was first developed, almost all of the horses and soldiers were immunized and Firor⁴⁴ wrote, in 1942, that among 16,000 wounded men only one immunized man is known to have developed tetanus and he had a light case. Halford,⁴⁵ writing of the treacherous disaster at Pearl Harbor, recorded that almost all of the Naval and Military personnel who were wounded had already been immunized with tetanus toxoid and received a booster dose afterward. Although the normal incidence of tetanus in Hawaiians was about 5.7 per 100,000 annually, no tetanus developed in the Pearl Harbor group. Whether the copious use of sulfanilamide contributed to this remarkable fact is quite uncertain, but Welch, Slocum, and Herwich⁴⁶ showed experimentally that sulfanilamide introduced along with massive doses of tetanus spores into deep pockets of skin failed to prevent the development of tetanus sixty-five to seventy days later in 4 out of 20 guinea pigs. Interestingly enough, the 16 animals receiving smaller doses of spores and not developing tetanus failed to do so even when they were subjected to crushing injuries, or injected with cultures of staphylococcus or a mixture of kaolin and calcium chloride.

Boyd and MacLennan⁴⁷ recorded 5 cases of tetanus, 3 of them fatal, in soldiers immunized with two doses of toxoid, indicating that "the immunity afforded by inoculation with tetanus toxoid has its ceiling." One of the fatal cases had shown little or no immunologic response and these authors emphasized the value of three inoculations. The other two fatal cases were attributed to overwhelming infections resulting from inadequate débridement of the wounds, indicating the essential role of adequate surgery in the prophylaxis of tetanus. Norman⁴⁸ described a case of tetanus in a soldier who had received two doses of tetanus toxoid. Recovery occurred after the administration of 200,000 units of antitoxin. The use of three doses of toxoid is said now to be customary in the British Army.

In the United States Army, according to Long,⁴⁹ where the use of three inoculations of tetanus toxoid has been practiced since 1941, no cases of tetanus have been reported in immunized individuals, but it would be unsafe to predict that cases of delayed tetanus may not still appear among the wounded personnel.

Returning now to the problem of tetanus in civilian populations, we find a different situation because active immunization against tetanus in civilians has been practiced only to a very limited extent. Smith,⁵⁰ in 1942, recorded 7 cases of tetanus in a sector of London during the first two years of the war. All the patients were civilians except one, a soldier who had not been immunized. There was one case of delayed tetanus, three and one-half months after 3,000 units of antitoxin. Smith suggested that the question of immunizing the civilian population should be discussed, but so far as I know, the general immunization of civilians in London or any other city has not been undertaken.

SUMMARY

Eleven cases of civil wounds out of a total of 2,493 in which debrided tissues were studied yielded *B. tetani*. Five of these wounds involved compound fractures, 5 involved lacerations, and 1 was caused by a burn. Up to the present

time none of them has developed tetanus. One case of tetanus developed following a burn in which *B. tetani* was not recovered from the débrided tissues.

I believe that, generally speaking, the bacteriologic examination of tissues débrided from fresh wounds can rarely if ever yield any information in time to be of practical value to the surgeon, that surgical procedures in any given case must of necessity be based upon general knowledge and empirical considerations, that the very earliest intimation of infection should be followed at once by competent and judicious microscopic examinations upon which intelligent surgical procedures may be based, and that cultures should then be made for confirmation and extension of existing knowledge.

The occasional delayed development of tetanus suggests that if the examination of débrided tissues is ever justified the search should especially be directed to *B. tetani* in order that patients in whom this organism occurs may be either actively immunized with tetanus toxoid or passively immunized with antitoxin in the event of a new surgical emergency. But the real practical value of even this type of examination must be considered at the present time to rest largely upon theoretical considerations.

The problems of delayed or idiopathic tetanus, the occurrence of *B. tetani* in wounds, and tetanus in World War II are reviewed.

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GYNECOMASTIA

II. A REPORT OF FIVE ADDITIONAL CASES

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IN A recent publication¹ I discussed certain aspects of a type of male breast enlargement classed as gynecomastia. Seven cases were reported and discussed and several conclusions were drawn from study of this series. Among them are: (1) The enlarged breast causes discomfort; (2) other pathologic changes such as mastitis and neoplasm may be present, adding significance to the disease process and to the treatment; (3) prompt relief from symptoms and lasting cure are obtained through complete mastectomy which may be done satisfactorily through a transverse, infra-areolar incision.

Five additional patients have been observed and treated. The results of study and treatment are in accord with those obtained from the first seven cases, and are offered now in supplement to the conclusions of the original series.

In all, twelve patients with gynecomastia have now been observed under similar circumstances. All complained of soreness or tenderness from pressure. In spite of the resemblance of the breast in gynecomastia to the pubertal female breast, the similarity apparently ends in its gross appearance. This is not simply an issue of masculine consciousness of an enlarged breast (though this point is not without significance), but it is also a matter of discomfort; the uniformity of complaint leaves no doubt that this disease is symptomatogenic. Most of these patients were referred for treatment with diagnoses such as neoplasm, adenoma, swelling of breast of unknown origin, hematoma, and, simply, soreness of breast.

TABLE I. SUMMARY OF FIVE ADDITIONAL CASES OF GYNECOMASTIA

SE	AGE, RACE	DURA- TION	SIDE	TRAUMA	ENDOCRINE	DIS- CHARGE FROM NIPPLE	SYMPTOMS	PATHOLOGY REPORT
8	28 W	3 to 4 mo.	R	No	None	No	Soreness when run- ning and exercising and from pressure	Gynecomastia
9	22 W	5 yr.	R	No	None	No	Soreness from pres- sure and from pack strap	Gynecomastia
10	28 W	1 yr.	RL	No	Mumps and orchitis in childhood; mild fem- inization	No	Soreness left breast from pressure and pack strap; no symptoms right breast	Gynecomastia, bi- lateral; left ex- hibits more epi- thelial hyper- plasia, of ducts than right
11	25 W	4 mo.	R	No	None	No	Increasing swelling, soreness, and pain; soreness from pack strap	Gynecomastia
12	19 W	1½ mo.	L	Bruise while wrestling 2 weeks before swelling	None	No	Steady growth; ten- derness from pres- sure; breast irri- tated by pressure of clothes	Gynecomastia

Two cases in the present series deserve special comment. Patient 8 reported because of worry as much as because of discomfort. Four years previously his left breast had been excised, together with the nipple, because of a preoperative diagnosis of cancer. The size of the breast and the symptoms reported as having been present then were matched by those presented currently. A preoperative diagnosis of gynecomastia of the right breast was made, and the right breast was excised. The breast exhibited the typical gross and microscopic characteristics of this disease. It is not too surprising that a radical operation was done on the left breast for what was supposed to have been a benign condition, for those who have not seen many cases of gynecomastia, and who have not recognized the occasional case, may think first of malignancy. Fig. 1 illustrates the nonmutilating incision on the right side, as employed in this entire series; it is to be compared with the radical incision used to remove the left breast. This patient's happy subjective postoperative reaction is reiteration of the conclusion that complete excision of the breast, through the illustrated infra-areolar incision, yields a very satisfactory result.

Case 10 was interesting. The patient was a 28-year-old white soldier who had complained of soreness in the left breast for one year. He had been hospitalized once for twenty-one days and for seven days on another occasion, and

had been treated with hot packs at these times. Symptomatic improvement occurred during hospitalization. There was prompt relapse, however, and the soldier reported several additional times on sick call. Enlargement of both breasts was found on examination, although there was no complaint referable to the right breast. There probably was some endocrine disturbance, for there was a history of mumps and orchitis in early childhood. The testicles were small and there were stigmas of feminization, such as lack of hair on the chest, sparse hair on the face, and a female escutcheon. Additional evidence is offered by the fact of bilateral breast involvement, even though it did not occur until this comparatively late age. However, in other respects there was no deviation from the masculine pattern and the patient reported normal libido and satisfactory sexual activity. Although only the left breast was symptomatic, both breasts

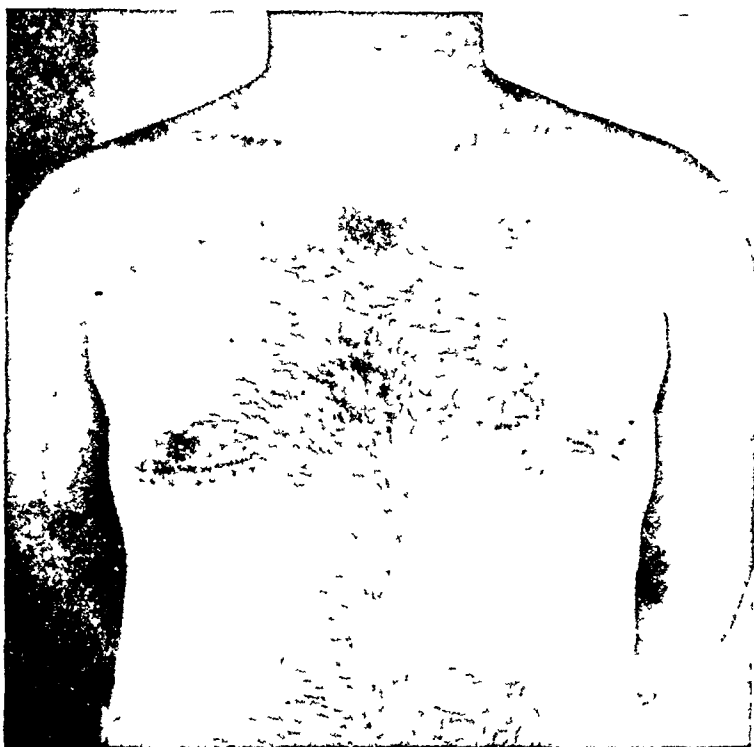


Fig. 1.—Patient 8 one month after right mastectomy, left mastectomy four years previously

presented the histologic picture typical of gynecomastia. The left side, in addition, exhibited moderately edematous stroma and slight epithelial hyperplasia of the ducts. This patient was very grateful for the relief afforded him by mastectomy. He was so much improved that no doubt need exist that the several conservative measures employed in treating him during the previous year caused loss of time and created dissatisfaction.

CONCLUSIONS OF PRESENT SERIES OF FIVE CASES

1. Gynecomastia may be unilateral or bilateral. It is a disease of unknown origin which may be confused clinically with several other diseases of the breast
2. Prompt relief of symptoms and permanent cure were obtained through complete mastectomy, as in the original series of seven cases.
3. The infra-areolar, transverse incision permitted complete excision of the breast, and is considered very satisfactory from the cosmetic viewpoint also

4. The basic histologic picture in these five cases resembled that of the first seven cases: there were scattered ducts lying in poorly cellular collagenous connective tissue. The ducts were lined by one to three layers of columnar epithelium. Slight round-cell infiltration of the periductal stroma was seen in a few instances.

COMMENT ON THE SERIES OF TWELVE CASES

Although the enlarged breast of gynecomastia has been referred to as homologous with virginal hypertrophy of the female breast, no symptoms comparable to those presented by the soldier with gynecomastia are observed in the female whose breast is undergoing pubertal enlargement. Nor, if conclusions are to be drawn from this series, are pathologic changes of similar quality and frequency to be seen in the prepubertal or pubertal female breast. In this series, five breasts presented pathologic change of significance in addition to gynecomastia. This is out of proportion to the incidence of pathologic change in the female breast at any age, and particularly at the age in which the breast is at a stage of development similar to that of the breast of gynecomastia.

These superimposed features represented inflammation, irritation, and premalignancy. The finding of an intraductal papilloma with metaplasia is significant. Boyd states "there appears to be a definite relation between duct papilloma and duct carcinoma." It is to be doubted that conservative therapy of any type would suffice in such an instance or in instances such as those found in Cases 10 or 4,¹ where the relief by excision was dramatic after two years of discomfort. The high incidence of pathologic change in the breast of underlying gynecomastia and the universal symptomatology are, therefore, strong factors in distinguishing gynecomastia as a disease requiring specific treatment.

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A CASE REPORT OF BILATERAL ARTERIOVENOUS ANEURYSMS OF THE POSTERIOR TIBIAL ARTERIES

WITH AN INTERESTING OBSERVATION CONCERNING THE EFFECT OF VASODILATATION

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UP TO the present time, bilateral arteriovenous aneurysms occurring simultaneously in a patient have seldom, if ever, been reported. Aside from the rarity of the condition the management of such cases is no different than that of those cases in which only one arteriovenous aneurysm is present. However, it is well to re-emphasize that arteriovenous aneurysms are not infrequent in men receiving war injuries, especially certain types of injury. In general, grenades, mortars, and similar kinds of shells on exploding produce, literally speaking, showers of fragments both large and small, so that it is not infrequent for a soldier being in the close vicinity of such an exploding shell to have

scores of small fragments penetrate the body. X-ray examinations of some such patients resemble those of patients who have received a concentrated load of buckshot, except that the fragments vary in size.

It is obviously both impossible and impractical in such cases to remove all the foreign bodies unless there is some specific reason for so doing, as for instance, infection or irritation to some structure in the region of the imbedded foreign body.

In those instances in which blood vessels are injured, it is quite often impossible to know definitely in the beginning whether or not the vessel has been injured unless a hematoma large enough to palpate develops suddenly or a pulsating hematoma appears. In other instances, segmental arterial spasm may develop, and, if a vessel of sufficient caliber is injured, this condition can be recognized clinically without having special diagnostic equipment, as an oscillogram, arteriography, or other special method or examination.

The time interval that may exist between the time of injury and the onset of the development of the arteriovenous aneurysm may vary widely between days and months or in some cases even longer. No definite rule can be made relative to the time elapsing between the time of injury and the development of the fistula, nor to the size of the fistula. However, there are definite means by which one can and should evaluate the fistula or fistulas in each individual case and it is by employing the collected data in each case and evaluating properly that one can arrive at a correct method for handling the case.

The evaluation of the signs and symptoms of arteriovenous aneurysms has been enumerated and emphasized many times by R. Matas, Mont Reid, E. Holman, and many others. Reid and Andrews¹ devised the following outline for evaluating arteriovenous aneurysms and it takes into consideration all of the most important points.

1. Effect on the collateral circulation
2. Effect on the involved vessels
3. Effect on the heart
4. Effect on the blood pressure
5. Effect on the circulatory balance
6. Effect on the nutrition of the part beyond

In those cases in which the smaller distal arteries are involved as the anterior and posterior tibials and also the radial and ulnar arteries in which smaller fistulas are present, there will be no discernible clinical changes in the size of the heart, nor changes in the blood pressure or the pulse rate following occlusion of the fistula, and no effect on the circulatory balance. However, there may be changes in the nutrition of the part distal to the fistula. These changes may be very minimal and the most noteworthy sign may be only a greater prominence of the veins on the affected side than on the uninvolved side. There is one other symptom that these patients may complain of and that is intermittent changes of a functional nature in the nerve distal to the fistula and in the vicinity of the involved vessels; usually it is described as a hyperesthesia distal to the site of the fistula. The question may arise in such instances as to whether or not the nerve was injured at the time of the original injury. If such was the case, the signs of nerve injury would not be of such an intermittent character.

There are, as has been repeatedly emphasized by many investigators, two courses of action that one may follow in the management of such cases of small arteriovenous aneurysms. One is operative, and the other rest and observation.

In the instances in which it has been determined that only a very small distal fistula is present, there is certainly no harm in observing the patient for some time with the expectation that it may close spontaneously. However, the thrill that is present over the fistula and transmitted along the veins may be a source of worry and of annoyance to the patient. In such instances, and in those cases in which a compensation element is involved, it is probably much better to have surgery performed presently than to wait an indefinite period of time. Surgery should always be postponed until adequate collateral circulation is present. In those cases in which there are definite signs of impaired nutrition to the part distal to the fistula or in which systemic effects are present, there is no question but that surgery should be performed when adequate collateral circulation is present.

Gage^{2, 3} has demonstrated and reported the effectiveness of sympathetic block as a preoperative measure in the surgical treatment of aneurysms of the peripheral arteries.

DeBakey^{4, 5} has described one case of arteriovenous aneurysm between the internal carotid and cavernous sinus in which cervicodorsal sympathectomy produced a cessation of symptoms.

In this regard the effects of sympathetic interruption on the case of arteriovenous aneurysm to be reported here should be of interest. It is my opinion that besides the beneficial effects which this procedure produces on collateral circulation, it may be of some value in arteriovenous fistulas in determining the size of the fistula. Either spinal anesthesia or lumbar sympathetic ganglion block produces vasodilatation of the lower extremity vessels, and with the consequent decrease of peripheral resistance the thrill and bruit will disappear in those cases of small arteriovenous fistulas. In the case to be reported, this was repeated twice, as it was believed that the fistula may have closed spontaneously the first time. If the fistula is large enough it would obviously not disappear with removal of vasomotor tonus and, thus, decreasing of peripheral resistance. There may be some other explanation for the disappearance of the signs of the fistula than the one given.

CASE REPORT

A 24-year-old white infantry officer was wounded in action, March 19, 1944, at which time he sustained multiple soft tissue wounds to both legs due to mortar shell fragment. The wounds were surgically cleansed and a cast was applied to the left leg because of some loss of soft tissue over the gastrocnemius; there was also an injury to the left superficial peroneal nerve. He was admitted to this hospital April 14, 1944. One week after the patient entered the hospital, the cast was removed and the soft tissue wounds were all found healed. One week later it was found that there was a definite thrill present at about the level of the middle and lower third of the left posterior tibial artery. The murmur could be heard over the veins of the leg and thigh. Because of the similar multiple wounds over the right leg, it was examined very carefully and no fistula could be found. However, because of the suddenness of the development of the fistula of the left leg, the right leg was examined each day. On the sixth day after the development of the fistula of the left leg, definite signs of a fistula were found in the right leg. It was situated at the level of the middle and lower third of the right posterior tibial artery. Pressure dressings and bed rest were prescribed for the patient. At this point the patient encouraged his friends who could walk to feel his legs; the doctors were likewise interested. Even when both fistulas were occluded there was no change in his pulse rate. During the period of observation there were never any evidences of systemic effect nor of any changes in nutrition to the parts distal to the fistulas. Previous to the operation it was definitely determined by complete obliteration of the pulses in the region of the fistulas that there was adequate collateral circulation.

The arteriovenous fistula on the left side was operated upon May 24, 1944, and a fistula was found near the middle and upper third of the posterior tibial artery. Imbedded

in the muscle about 1 cm. from the fistula, a small metallic fragment was found. The fistula was about 5 mm. long and the lumen about 1 mm. in diameter, extending in an oblique direction between the artery and the vein. There was no evidence of injury to the nerve in this region. There was little scar tissue here and the fistula was ligated doubly, immediately adjacent to both the artery and the vein, with 000 silk and excised between the ligatures. It is recognized that there are other surgical procedures that in all cases, generally speaking, are superior to the method used in this case, as for example quadruple ligation and excision, yet it was felt that in this particular case the procedure employed was adequate. No evidence of recurrence developed.

The arteriovenous fistula on the right side was operated upon June 22, 1944. All signs of the fistula disappeared after the induction of the spinal anesthetic and in this instance the fistula could not be found. It was felt because the physical signs were much less pronounced on this side, that an extensive dissection to find it would not be justifiable in such a small fistula as was presumed to be present. At the time the patient was discharged from this hospital the thrill and continuous machinelike murmur were present.

CONCLUSIONS

1. A case of bilateral arteriovenous fistula of the right and left posterior tibial arteries is presented.

2. Attention is directed to their probable more frequent occurrence in patients sustaining multiple small wounds from mortar and grenade fragments than from those caused by larger missiles.

3. Attention is also directed to the possible value of determining the size, whether large or small, of a fistula in a terminal or distal vessel by instituting spinal anesthesia or lumbar sympathetic paravertebral shock, obliterating vasomotor tonus, and decreasing peripheral resistance.

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AN IMPROVED METHOD OF CIRCUMCISION

USE OF RELAXATION INCISIONS, COTTON LIGATURES AND SUTURES

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ALTHOUGH circumcision has been performed since the days of antiquity and there are now a number of accepted methods, any improvement in technique should be worth while. I have performed more than 600 circumcisions at an Army station hospital during a four-year period (1941 to 1945). The patients were soldiers who had severe phimosis and its complications, such as acute and chronic balanoposthitis or condyloma acuminata. Various methods of circumcision which have been described in the literature have been tried. The procedure which is now followed at this hospital involves the use of relaxa-

tion incisions, cotton ligatures, and cotton sutures. This technique has given uniformly more satisfactory results than the other procedures which were previously employed. Postoperative swelling, pain, and discomfort are diminished, and healing is hastened.

PROCEDURE

The following routine is employed. The patient is admitted to the urologic ward. He shaves the external genitalia and bathes, paying particular attention to cleansing of the genitals. If the prepuce cannot be retracted, the

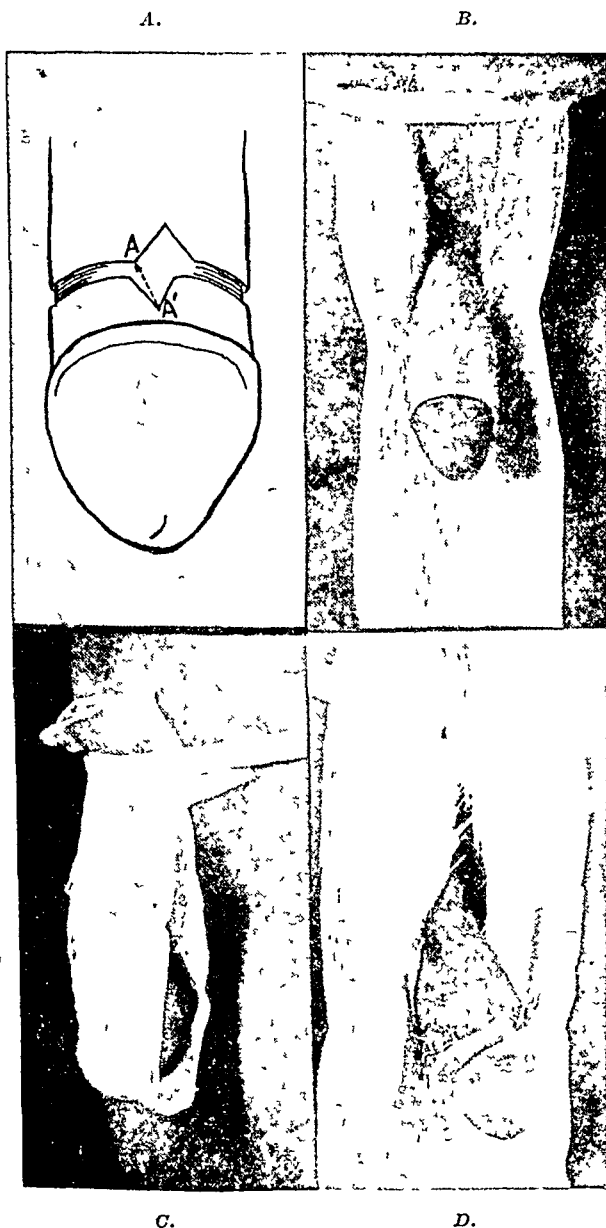


Fig. 1.—A, Showing V-shaped notches in cut edges of skin, when skin sutures are placed, A will be approximated to A¹. B, Sterile petrolatum gauze dressing has been applied, and the protective "gauze apron" is being placed in position. C, Dressing completed. D, Appearance on fourth postoperative day before removal of skin sutures.

preputial sac is irrigated with a 1:5,000 solution of potassium permanganate by the ward attendant. The patient is permitted to have a light breakfast, and is given sodium amytal, 0.194 Gm. (3 gr.), one hour prior to operation.

Book Reviews

An Outline of Tropical Medicine. By Otto Saphir, M.D. Chicago, 1944, The Michael Reese Research Foundation.

This small volume is the first publication by the Michael Reese Research Foundation for the Michael Reese Hospital of Chicago. In the introduction the author states, "This outline summarizes the barest essentials of the more important diseases encountered in the study of Tropical Medicine. It is neither a textbook nor a handbook. It is in no respect a complete treatise, but merely an outline in the strictest sense of the word. It perhaps can be described best as an extended vocabulary of Tropical Medicine." The reviewer agrees with this statement of the purpose of the volume. Significant tropical diseases are concisely described, particularly from the clinical point of view. References to more extended discussions of the diseases are appended to each chapter. The text is well indexed. For the average clinician, more comprehensive information will be necessary than is to be found in Saphir's book. It is difficult to ascertain for whom this outline has been prepared.

The Urinary Tract. A Handbook of Roentgen Diagnosis. By H. Dabney Kerr, M.D., and Carl L. Gillies, M.D., Chicago, 1944, The Year Book Publishers, Inc.

This small handbook is most compact and may well be the best book on the urinary tract from a roentgenologic standpoint. The material used in the preparation of the book has been obtained entirely from the records of the University Hospital of Iowa and the authors have examined and verified all the cases themselves. Consequently the book represents the experience and judgment of the authors and is not a review of the literature.

Practically every other page in the book is filled with reproductions of radiographs, the opposite page containing the description of the views. This makes for very easy reading of the text and ready reference to the roentgenogram being described. The authors did all the photographic work themselves, which probably accounts in part for the excellent reproductions. Because there are so many variations in abnormal as well as normal conditions, many examples of each condition are included.

The text begins with a brief discussion on preparation for urographic examinations in which the authors state that no routine preparation is used for most of their examinations.

The section on kidneys includes a good selection of normal pyelograms, chiefly retrograde studies, because the authors feel that anatomy can be better demonstrated by this method than by intravenous pyelograms. There is a fine discussion on pyelorenal backflow, congenital anomalies, and movable kidneys with excellent illustrations. Urinary stones are then discussed with illustrations of all the other calcifications which might be confusing. A relatively new entity known as calyceal diverticulum is described and amply illustrated. This is followed by a long series of illustrations of all types of infections including formations of gas in urinary tract with infections. The final kidney section takes up tumors. At least one-third of the tumors show calcification. They feel retrograde studies are the best for the demonstration of tumors and also feel that distortion of the kidney outline is of prime importance.

The ureter is taken up in the second section of the book, which deals primarily with ureteral stones, but has good illustrations of anomalies, ureterectasis, and tuberculosis. There is no mention of ureteritis cystica and no illustrations of the deformity of the bladder occasionally seen around the ureteral orifice associated with a ureteral stone as it passes through the distal end of the ureter.

The third section of the book is concerned with the bladder. This is a very complete section with many excellent illustrations. Some unusual things are described and illustrated, such as an inguinal hernia containing the bladder, cystitis emphysematosa, tumor in a

diverticulum, and bladder tumors resulting from implants of kidney tumors. The authors also state that the bony deformities of the pelvis commonly associated with extrophy of the bladder may also be present with epispadias and bifurcation of the clitoris. They feel air cystograms are better for showing most bladder tumors and bladder stones which are very often uric acid stones.

The last section of the book takes up the urethra. It is a surprise to find that this is the second largest part of the book. The average radiologist and urologist places little emphasis on this part of the urinary tract from a roentgenographic standpoint. An excellent method of cysto-urethrography has been developed by Dr. Rubin H. Flocks, a urologist at the University of Iowa, and this is described in detail. Using this method the urologists apparently study a large percentage of their cases of prostatic hypertrophy. In the book the discussions and illustrations of prostate enlargement occupy more space than any other entity. The individual lobes of the prostate are visualized and it is possible to determine which lobes are enlarged. Many times carcinoma of the prostate produces a characteristic picture. This is also true of the neurogenic bladder. Most of this section is devoted to the posterior urethra, but there is also a short portion on the anterior urethra with a discussion of the differentiation of gonorrheal urethritis and strictures from traumatic strictures.

The book is enthusiastically recommended.

Operations of General Surgery. By Thomas G. Orr, M.D., Professor of Surgery, University of Kansas School of Medicine. Pp. 723. Kansas City, Kan., 1944. W. B. Saunders Company.

This text on the technique of operations of general surgery by one of America's well known surgeons is well done. Orr has succeeded in compressing into a single volume the technical procedures of a large broad field commonly referred to as general surgery—a province upon which the surgical specialists have made rather serious inroads. It is quite a feat in itself for a surgeon today who essays to do general surgery to write a text which embraces a good portion of all of operative surgery. There was a time, and not so long ago, that a single author text on operative surgery was not unusual. In more recent years, however, surgeons have concerned themselves more with attempts at achieving mastery in a single field rather than in many fields. In consequence, surgeons have found it necessary to acquaint themselves with a number of items relating to the field, which might be regarded as essentially non-surgical. This more ruminative attitude of the surgeon toward his work has improved the character of the surgery in fields where this practice is commonplace. Overspecialization, however, can lead to sterility just as certainly as studied efforts to achieve a uniform versatility in all fields. There is undoubtedly a middle ground for the surgeon in his work. The very breadth of surgery suggests, however, that this book by a distinguished American surgeon perhaps is one of the last of its line. In other words, the multiple-author technique of dealing with many subjects, in the main, has come to supplant the treatment of a large number of related subjects by a single author.

Structure and Function as Seen in the Foot. By Frederic Wood Jones, D.Sc., F.R.S., F.R.C.S. Baltimore, 1944, Williams & Wilkins Company. \$7.50.

Wood Jones has given to us one of the most readable books on the anatomy of the foot that the reviewer has been privileged to peruse. He has discussed, both from the anatomic and from the anthropologic aspect, the importance of the foot to man's locomotor mechanism. The author's extremely interesting style of writing has made the review of this book very easy and thought provoking.

The statement that the distinct design of the foot separates man from all other forms of vertebrate life as much as any organ of the body, may give rise to much controversy of opinion. However, the reviewer feels that Wood Jones has presented enough evidence in his book to substantiate this remark.

The author emphasizes that the human foot has changed remarkably in its development from that of a grasping organ to that of a weight-bearing organ, while the human hand,

which always has been a grasping organ, has remained so but has been more highly developed. This is a concept that most anatomists have not presented before.

The author's discussion of muscle action is most interesting. In comparing the action of muscles in the forearm and in the foot, the author states that in the forearm the muscle origins, which are located proximally, serve as fixed points from which the movements of the digits in the hands are effected. However, in the lower extremity the tendinous insertions upon the distal bony segments serve as fixed points from which muscle action is enabled to control posture and movements of body weight.

Wood Jones has covered the make-up of the foot from the skin down to the bone and he has given a very comprehensive discussion on all the structures of the foot. The morphology of the foot is discussed at some length.

In conclusion, the author has not discussed the physiology of the foot function to any extent. With such a fine comprehensive review of the anatomy of the foot and its structures, a thorough discussion of the function and physiology of the foot would add to the interest of the book.

The volume is highly recommended to all men interested in the anatomy of the foot and especially to the orthopedist, as it will give him a new insight and concept of the function of the foot.

Shoulder Lesions. By H. F. Moseley, M.D., Springfield, Ill., 1945, Charles C Thomas.

This 180 page book is further evidence that the complex mechanism of the shoulder is gradually becoming better understood. Moseley shows that even this intricate member can be reduced to straightforward pathology and physiology. Each chapter is followed by a bibliography. Illustrations are graphic.

Twelve pages are devoted to functional anatomy. The Examination is discussed in four pages. A chapter on Rupture of the Rotator Cuff is most valuable. The identity of this group of injuries has been confused and misunderstood for too long. The other lesions, including bicipital syndromes, are also analyzed from the standpoint of pathology, diagnosis, and treatment. Francis L. McNaughton contributes the chapter on Neurological Aspects of Shoulder Pain. X-ray Diagnosis and Treatment is reviewed by Jean Bouchard and C. B. Peirce.

Indicative of the thoroughness with which the subject is handled are discussions of surgical approach and technique and of re-education programs for shoulder function. Twenty-two pages are given to case records. The subject is yet far from exhausted. Perhaps Moseley will see fit to add subsequent editions as new information comes to light. The book should be a part of every medical library.

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A REVIEW OF PATIENTS WITH INTRATHORACIC DISEASE AND INJURY TREATED ON THE SURGICAL SERVICE OF A UNITED STATES ARMY GENERAL HOSPITAL IN NORTH AFRICA

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INTRODUCTION

THIS report deals with 81 patients admitted to the Chest Division of the Surgical Service of a United States Army General Hospital during the period of its operation in North Africa during the spring, summer, and fall in 1943. This hospital's installations were all in Nissen huts and tents. Until the end of the Tunisian Campaign it was the most forward of any of the American general hospitals in North Africa. Due to its forward location and the recurring need for a large number of available beds to care for the casualties resulting from the bitter fighting of the last weeks of the war in Africa, it was impossible to keep some patients for periods longer than three weeks. The same thing was true, but to a lesser extent, at the time of the invasion of Sicily. Even at the busiest periods, however, the hospital was not called upon to give primary surgical treatment to any battle casualties except in a few isolated instances.

Only those patients with intrathoracic disease or injuries involving the thoracic cavity are considered in this report. Wounds involving the thoracic wall alone have been excluded since such wounds present no special problems not found in other wounds. Neither have patients with fractured ribs unassociated with intrathoracic complications been included. Many of the 81 patients had other wounds but these wounds did not appear to affect the course of the intrathoracic injuries, and for the purposes of this report have been neglected.

MISCELLANEOUS CASES

The 5 miscellaneous cases represented pathologic processes such as may be encountered in any general hospital in civil life.

One soldier presented a far-advanced fibrosarcoma of the chest wall which appeared to have followed an injury during training in the air-borne infantry. Biopsy of the tumor and aspiration of the chest to relieve dyspnea were the only procedures indicated.

Another patient was admitted with empyema of the right pleural cavity secondary to subphrenic abscess following a ruptured appendix. At the time

TABLE I. CLASSIFICATION OF PATIENTS WITH INTRATHORACIC INJURIES OR PATHOLOGY

Cases of a miscellaneous character	5
Cases of nonpenetrating injuries	10
Cases of penetrating wounds	66
Total	81

of his admittance, the subphrenic abscess had been drained anteriorly. Rib resection and open drainage gave satisfactory immediate results.

Two patients with mediastinal tumors were seen. One of these tumors was thought to be a mass of partially calcified lymph nodes and was not operated upon. The second was operated upon and a teratoid tumor, approximately 10 cm. in diameter, was removed with considerable difficulty. During the closure of the thoracic wall a fatal hemorrhage occurred from the aorta at a point where the tumor had been closely adherent. The remaining 4 patients in this group were returned to the United States for further treatment.

CASES OF NONPENETRATING INJURY

Ten patients with nonpenetrating injuries of the thoracic cavity were encountered. Seven of these injuries were due to motor vehicle accidents and 3 were battle casualties. These patients were all treated initially at other hospitals and transferred to us during the early part of their convalescence. Other injuries present besides the chest injuries included lacerations, contusions, and cerebral concussion. Two patients with blast injuries from bomb explosions had large pneumothoraces. One of these pneumothoraces was of the tension type and necessitated continuous aspiration of the pleural cavity for eight hours at an evacuation hospital. Fractured ribs were present in all these 10 patients and in 4 instances ribs on both sides were involved. Hemothorax, pneumothorax, and subcutaneous emphysema were seen singly or in various combinations in all these cases.

Treatment at our hospital consisted only of strapping of the chest with adhesive tape when necessary to give comfort, and aspiration of the intrapleural blood and air when present in any but minimal amounts. One exception to this was a soldier who developed an empyema necessitating closed drainage.

None of the patients in this group died. Two were returned to duty sixty and sixty-two days, respectively, after injury. The remainder was evacuated to general hospitals further back or directly to the United States to complete their convalescence.

CASES OF PENETRATING INJURIES OF THE CHEST

Sixty-six patients were seen who had penetrating wounds of the thoracic cavity. These were all battle casualties, with three exceptions. A corporal (Case 11, Table V) was injured during battle training when a mortar shell fell short. A shell fragment penetrated through the right pleural cavity and lodged in the muscles beneath the right scapula. This patient was operated upon. Lacerations in the superior vena cava and right lung were sutured and a large quantity of blood removed from the right pleural cavity. A portion of this was returned to the patient by vein. A private (Case 12, Table IV) was stabbed by another soldier during the course of an argument. A lieutenant (Case 1, Table V) was accidentally stabbed during a volleyball game by the knife of a fellow player who had neglected to remove it from his belt.

TABLE II. PATIENTS IN WHOM INJURY WAS NOT CONFINED TO THE THORACIC CAVITY

INJURY	NO. OF PATIENTS
Lung and diaphragm	2
Liver and diaphragm	2
Lung, liver, and diaphragm	2
Total	6

This large group of patients from the standpoint of surgical therapy falls naturally into three classes as follows:

1. Patients treated without primary surgery other than débridement and without subsequent aspiration of the pleural cavity, 15.
2. Patients treated without primary surgery other than débridement and with subsequent aspiration of the pleural cavity, 33.
3. Patients treated with primary major surgery, 18.

In a somewhat rough manner this classification also divides the patients according to the severity of their injuries. There are, however, some exceptions. The large majority of patients with penetrating wounds of the thoracic cavity had had the wound of the chest wall débrided in the forward hospitals. In a few instances in which the wounds were small and the resulting injury minimal, no débridement at all had been done. No débridements were performed at our hospital in any of the chest cases except in the instance of case 11, Table V, mentioned previously. No wounds were of the sucking variety when seen at our hospital, although many were noted on the field medical record as being

TABLE III. PATIENTS WITH PENETRATING INJURIES OF THE THORAX TREATED WITHOUT PRIMARY SURGERY OTHER THAN SUPERFICIAL DÉBRIDEMENT AND WITHOUT SUBSEQUENT ASPIRATION OF THE PLEURAL CAVITY

CASE	CAUSE OF INJURY	TYPE OF INJURY	RETAINED FOREIGN BODY	RESULTS
1	Shell fragment	Laceration of lung, hemothorax, fractured rib, left	No	Evacuated, improved
2	Mortar shell fragment	Laceration of lung	Yes	Returned to duty, recovered
3	Shell fragment	Laceration of lung	Yes	Returned to duty, recovered
4	Machine gun bullet	Laceration of lung	No	Evacuated, improved
5	Bomb fragments	Laceration of lung, hemothorax	Yes	Evacuated, improved
6	Mortar shell fragments	Laceration of lung, pneumothorax	Yes	Evacuated, improved
7	Shell fragment	Laceration of lung	Yes	Evacuated, improved
8	Shell fragment	Laceration of lung, hemothorax	Yes	Returned to duty, recovered
9	Mortar shell fragments	Laceration of lung	Yes	Evacuated, improved
10	Rifle bullet	Laceration of lung, pneumothorax, fractured ribs, right	No	Evacuated, improved
11	Mortar shell fragment	Laceration of lung	Yes	Returned to duty, recovered
12	Rifle bullet	Laceration of lung, pneumothorax	No	Evacuated, improved
13	Shell fragments	Laceration of lung	Yes	Returned to duty, recovered
14	Shell fragment	Laceration of lung, hemothorax	No	Evacuated, improved
15	Shell fragment	Laceration of lung, hemothorax	No	Evacuated, improved

*This patient developed a localized empyema at the site of exit of the fragment which also shattered the rib. A resulting bronchial fistula was closed and the empyema cavity obliterated by operation.

TABLE IV. PATIENTS WITH PENETRATING INJURIES OF THE THORAX TREATED WITHOUT PRIMARY SURGERY OTHER THAN SUPERFICIAL DÉBRIDEMENT AND WITH SUBSEQUENT ASPIRATION OF THE PLEURAL CAVITY

CASE	CAUSE OF INJURY	TYPE OF INJURY	RETAINED FOREIGN BODY	COMPLICATIONS	AMOUNT OF FLUID ASPIRATED (C.C.)	RESULTS
1	Shell fragments	Laceration of lung, hemothorax, fractured rib, right	No	None	345	Returned to duty, recovered
2	Shell fragments	Laceration of lung, hemothorax	Yes	None	3,520	Evacuated, improved
3	Shell fragment	Laceration of lung, hemothorax	No	Empyema, bronchial fistula	650	Evacuated, improved
4	Shell fragment	Laceration of lung, hemothorax	No	None	1,150	Evacuated, improved
5	Shell fragments	Laceration of lung, hemothorax	No	Empyema, bronchial fistula	1,400	Evacuated, improved
6	Machine gun bullet	Laceration of lung, hemothorax, fractured rib, left	No	None	More than 100	Returned to duty, recovered
7	Rifle bullet	Laceration of lung, hemothorax, pneumothorax	No	None	1,110	Returned to duty, recovered
8	Shell fragment	Laceration of lung, hemothorax, pneumothorax, fractured ribs, left	No	None	1,400	Evacuated, improved
9	Rifle bullet	Laceration of lung, hemothorax, fractured ribs, left	No	None	1,000	Evacuated, improved
10	Machine gun bullet	Laceration of lung, hemothorax, pneumothorax	No	None	700	Evacuated, improved
11	Shell fragment	Laceration of lung, hemothorax	Yes	Coagulation of intrapleural blood with beginning organization	2,675	Evacuated, improved
12	Knife	Wound of liver, diaphragm, and lung, hemothorax	No	None	1,700	Evacuated, improved
13	Machine gun bullet	Laceration of lung, hemothorax, pneumothorax, fractured rib, left	No	None	2,155	Returned to duty, recovered
14	Machine gun bullet	Laceration of lung, hemothorax, pneumothorax	No	None	915	Evacuated, improved
15	Rifle bullet	Laceration of lung, hemothorax, pneumothorax	No	None	800	Evacuated, improved
16	Pistol bullet	Laceration of lung, hemothorax, pneumothorax, subcutaneous emphysema, fractured clavicle, right	No	None	2,970	Returned to duty, improved
17	Pistol bullet	Laceration of lung, hemothorax, pneumothorax	No	None	1,320	Returned to duty, recovered
18	Shell fragment	Laceration of lung, hemothorax, pneumothorax, fractured rib, right	No	Coagulation of intrapleural blood with beginning organization	2,060	Returned to duty, recovered
19	Shell fragment	Laceration of lung, hemothorax	No	None	350	Evacuated, improved
20	Shell fragment	Laceration of lung, hemothorax	Yes	None	50	Evacuated, improved

TABLE IV—CONT'D

CASE	CAUSE OF INJURY*	TYPE OF INJURY	RETAINED FOREIGN BODY	COMPLICATIONS	AMOUNT OF FLUID ASPIRATED (C.C.)	RESULTS
21	Machine gun bullet	Laceration of lung, hemothorax, fractured rib, left	No	None	650	Evacuated, improved
22	Shell fragment	Laceration of lung, hemothorax	No	None		Evacuated, improved
23	Rifle bullet	Laceration of lung, hemothorax	No	None		Evacuated, improved
24	Shell fragment	Laceration of lung, hemothorax	Yes	None	2,400	Evacuated, improved
25	Bomb fragment	Laceration of lung, hemothorax	No	None	1,775	Returned to duty, recovered
26	Machine gun bullet	Laceration of lung, hemothorax	No	Empyema, bronchial fistula		Evacuated, improved
27	Shell fragment	Laceration of lung, hemothorax, pneumothorax	Yes	None	700	Evacuated, improved
28	Shell fragment	Laceration of lung, hemothorax	Yes	Coagulation of intra-pleural blood with beginning organization	2,000	Evacuated, improved
29	Shell fragment	Laceration of lung, hemothorax, fractured rib, left	Yes	None	700	Evacuated, improved
30	Machine gun bullet	Laceration of liver and diaphragm, hemothorax	No	Empyema		Evacuated, improved
31	Rifle bullet	Laceration of lung, hemothorax	No	None		Return to duty, recovered
32	Shell fragment	Laceration of lung, hemothorax	Yes	Empyema, bronchial fistula		Evacuated, improved
33	Shell fragment	Laceration of lung, hemothorax, pneumothorax, severance of spinal cord	No	Empyema, bronchial fistula	3,140	Evacuated, improved

such initially. Ribs were frequently noted to have been fractured by the penetrating missiles but this complication provided no special therapeutic problem in any of our cases.

As can be seen from Tables II to V, bomb, mortar, and shell fragments were by far the most frequent causative agents with machine gun, rifle, and pistol bullets accounting for the remainder of the battle casualties.

Thoraco-Abdominal Injuries.—According to a strict interpretation of the term, 6 patients might be classified separately as having thoraco-abdominal wounds, but this has not been done. In only 4 of these patients was the liver injured and in every instance the injury was slight. There were no other intra-peritoneal injuries. The injury to the diaphragm in all 6 cases was not great. None of these patients died or developed complications secondary to the wounds of the diaphragm or liver while under our observation.

1. Patients Treated Without Primary Surgery Other Than Débridement and Without Subsequent Aspiration of the Pleural Cavity

There were 15 patients in the group treated without primary surgery other than débridement and without subsequent aspiration of the pleural cavity. In some of these cases hemothorax, pneumothorax, or both were present in a minimal degree. Convalescence proceeded satisfactorily and aspiration was not

TABLE V. PATIENTS WITH PENETRATING WOUNDS OF THE THORAX TREATED WITH PRIMARY MAJOR SURGERY

CASE	CAUSE OF WOUND	TYPE OF WOUND	OPERATION	RETAINED FOREIGN BODY	PLEURAL SPACE DRAINAGE	FLUID ASPIRATED FROM PLEURAL SPACE AFTER OPERATION (C.C.)	RESULTS
1	Knife	Laceration of diaphragm and intercostal artery	<i>Thoracotomy</i> : Suture of diaphragm and ligation of intercostal artery	No	No	250	Returned to duty, recovered
2	Bomb fragments	Laceration of lung, fractured rib, left	<i>Thoracotomy</i> : Excision of foreign bodies and suture of lung	Yes	No	Not known	Evacuated, improved
3	Shell fragment	Laceration of lung, fractured rib, right	<i>Thoracotomy</i> : Suture of lung	Yes	No	Not known	Evacuated, improved
4	Shell fragment	Contusion of lung, fractured ribs, left	<i>Thoracotomy</i> : Exploration	No	Yes	75	Evacuated, improved
5	Shell fragment	Laceration of lung	<i>Thoracotomy</i> : Suture of lung	Yes	No	1,200	Returned to duty, recovered
6	Shell fragment	Laceration of lung, fractured rib, right	<i>Thoracotomy</i> : Partial lobectomy	No	No	25	Evacuated, improved
7	Rifle bullet	Laceration of lung, subcutaneous emphysema	<i>Thoracotomy</i> : Excision of foreign body and suture of lung	No	No	900	Evacuated, improved
8	Shell fragment	Laceration of lung	<i>Thoracotomy</i> : Suture of lung	Yes	No	485	Returned to duty, recovered
9	Mortar shell fragment	Laceration of lung	<i>Thoracotomy</i> : Excision of foreign body and suture of lung	No	No	Not known	Evacuated, improved
10	Shell fragment	Laceration of lung	<i>Thoracotomy</i> : Excision of foreign body and suture of lung	No	No	1,770	A.W.O.L., recovered
11	Mortar shell fragment	Laceration of superior vena cava and lung, fractured sternum	<i>Thoracotomy</i> : Suture of superior vena cava and lung	Yes	No	250	Evacuated, improved
12	Shell fragment	Laceration of lung	<i>Thoracotomy</i> : Excision of foreign body and suture of lung	No	Yes	Not known	Evacuated, improved
13	Shell fragment	Laceration of lung, subcutaneous emphysema	<i>Thoracotomy</i> : Excision of foreign body and suture of lung	No	Yes	Not known	Evacuated, improved
14	Shell fragment	Laceration of lung, liver, and diaphragm	<i>Thoracotomy</i> : Excision of foreign body and suture of diaphragm and lung	No	Yes	Not known	Evacuated, improved
15	Mine fragments	Laceration of lung and diaphragm	<i>Thoracotomy</i> : Suture of diaphragm and lung	No	No	Not known	Returned to duty, recovered
16	Mine fragments	Laceration of lung	<i>Thoracotomy</i> : Suture of lung	Yes	No	440	Evacuated, improved
17	Bomb fragments	Laceration of lung	<i>Thoracotomy</i> : Suture of lung	Yes	Yes	Not known	Evacuated, improved
18	Shell fragments	Laceration of liver and diaphragm	<i>Laparotomy</i> : Suture of diaphragm	No	No	Not known	Evacuated, improved

performed. Despite the presence of retained metallic foreign bodies in the lungs of 9 of these patients, no operative procedure for their removal was done. Complications developed in only 1 instance. This soldier developed a localized empyema with a bronchial fistula which had to be closed by operation. Five patients of this group were returned to duty sixteen to seventy-one days after receiving their wounds. The remainder was evacuated to the rear areas or to the United States. No patient died.

2. Patients Treated Without Primary Surgery Other Than Débridement and With Subsequent Aspiration of the Pleural Cavity

Thirty-three patients received penetrating wounds of the thorax not of sufficient magnitude to necessitate any primary surgery other than the débridement of the wound of the chest wall performed at the forward hospitals, but developed pneumothoraces and hemothoraces which required aspiration. In some cases only one aspiration was performed, while in others several aspirations were carried out. The total quantity of bloody fluid removed from the chests of these individuals varied from 50 to 3,520 c.c. The air, often removed simultaneously with the fluid, was not measured. In only 8 cases were there retained foreign bodies and no operations were performed at our hospital for their removal. Six of the 33 patients developed empyema and in 5 of these 6 there was an associated bronchial fistula. In only 1 case of empyema was there a retained foreign body.

In 3 cases an intrapleural hematoma became organized. Each of these patients was subjected to thoracotomy, the organizing hematoma removed, and the lung freed.

None of the 33 patients died. Nine patients were returned to duty after periods of treatment up to ninety-five days. The remainder was evacuated to other base hospitals or to the United States for further treatment.

3. Patients Treated With Primary Major Surgery

The 18 cases in which primary surgery was performed for the intrathoracic wound included 17 instances of thoracotomy and 1 instance of laparotomy. Only one of these operations was performed at our hospital. This patient (Case 11, Table V) has been mentioned previously. The usual procedure at the time of operation was to ligate all bleeding vessels and suture lacerated lung tissue. Only 1 patient had had a partial lobectomy. When received at our hospital, 7 of these patients had retained intrathoracic metallic foreign bodies demonstrable by x-ray examination. Thirteen patients were operated upon and cared for without postoperative drainage of the thoracic cavity. The other 5 were drained by catheter for two to four days after operation. Two patients developed complications: one (Case 9, Table V) had a severe wound infection in the chest wall, and another (Case 11, Table V) developed an intercostal neuritis which necessitated cutting two intercostal nerves proximal to the thoracotomy incision.

No patient died. Four were returned to duty at intervals up to forty-one days after injury. One patient left the hospital without leave fifty-two days after his injury. The remainder was evacuated to the rear or to the United States for prolonged convalescence.

DISCUSSION

Since almost all the patients with thoracic injuries were admitted to our hospital by way of transfer from more forwardly situated evacuation and

station hospitals, some two to fourteen days after being wounded, we were rarely called upon to determine how such patients were to be treated. Definitive treatment had already been started. By and large the patients arrived in good general condition considering the seriousness of their wounds. This speaks well for the large volume of work performed under trying circumstances by the evacuation hospitals. In most cases all that we could do was to ensure, as far as possible, the continuance of a satisfactory convalescence and to return to duty as many men as possible, physically fit to withstand sustained hard physical exertion.

To fulfill these duties properly, considerable thought was given to three problems. These were:

1. The treatment to be employed for accumulations of blood in the pleural cavity
2. The treatment to be employed for retained intrathoracic foreign bodies
3. Criteria to be employed in determining whether or not a patient was fit to return to duty

Six months is indeed a short time in which to answer such questions from our own somewhat meager experience but some decision which would serve as a working basis had to be found immediately.

We had been greatly impressed in 1942 by the results obtained in England by Mr. Tudor Edwards and his colleagues in the treatment of hemothorax following wounds of the chest by repeated aspiration. These men advocated repeated frequent aspirations, begun thirty-six to forty-eight hours after the occurrence of the hemorrhage and continued until no further fluid accumulated in the pleural space. Such a regimen seems justified by the facts, as demonstrated by Tudor Edwards, that early aspiration did not produce additional bleeding and that the incidence of infection was much lower in those patients in whom the pleural space was kept free of fluid by aspiration than in those treated conservatively, that is, without aspiration. An additional reason for the persistent use of aspiration is the very real danger of coagulation and subsequent organization of an intrapleural collection of blood.

A thoracentesis was performed in each case of thoracic wound or injury in which intrapleural fluid other than a minimal amount was thought to be present either by physical or x-ray examination. Routine use was made of the efficient portable electric suction pumps provided by the Army Medical Corps. The degree of suction produced by these machines can be quickly and accurately regulated by a control screw, and six months' experience has shown that the machines are safe when used carefully. Most of the patients were aspirated every third or fourth day as long as was required by the reaccumulation of the fluid. No arbitrary limit was set as to the quantity of fluid or air, or both, that should be removed at one time. The patient's subjective complaints of tightness, pain in the chest, or the onset of coughing were taken as indications to terminate the aspiration. On no occasion, however, were more than 900 c.c. of fluid removed at one time. The usual aspirations averaged between 400 and 600 c.c.

As practically all of our patients had been injured more than forty-eight hours before reaching the hospital, there seemed to be little danger of initiating fresh bleeding by the disturbance of intrathoracic pressure relationships due to thoracentesis. In only a few instances, therefore, was air injected following the aspiration and then only for the increased comfort of the patient. No instances in which aspiration produced renewed bleeding were noted.

From the information available, we feel unable to express any opinion as to the effect of aspiration in the development of the 9 cases of empyema present in this series. No case of empyema was seen to develop at this hospital, however, as a sequel to thoracentesis. All of those patients noted as having empyema had the infection when first admitted to the hospital. The incidence of empyema following wounds that penetrated the pleural cavities was approximately 11 per cent (7 out of a total of 66 wounds).

To illustrate the typical and satisfactory response to thoracentesis in a suitable case, the story of one soldier (Case 24, Table IV) can be told briefly.

CASE REPORT

This soldier experienced a penetrating wound of the left side of the chest from a small shell fragment Sept. 12, 1943, near Salerno, Italy. The skin wound was small in size, being 1 cm. in length and irregular in contour. The shell fragment was retained within the thoracic cavity. The wound in the chest wall was sucking in character. This was closed with one mattress suture as an emergency procedure at a field dressing station the day of the wound. In addition, the patient was given 1,000 c.c. of plasma. Following this he lay in a barn at the Salerno beach head for two days before being evacuated directly to our hospital by hospital ship and ambulance.

At the time of his admission to the hospital, Sept. 20, 1943, the left lung was totally collapsed and the mediastinum shifted to the right. Fluid and superimposed air filled the left pleural cavity. The patient was dyspneic and pale with a temperature that ranged between 101 and 103° F. Thoracenteses were performed September 21, 22, 24, 26, and 27 with a total of 2,400 c.c. of bloody fluid and a large quantity of air being removed. This fluid was found to be sterile by culture on three occasions and while containing approximately 35 per cent hemoglobin at the first aspiration, became more serous in character at each aspiration. The temperature remained elevated for four days until all sulfonamide drugs were omitted. These had been given in large doses irregularly since the day he had received the wound. Subsequent therapeutic trial proved him sensitive to these drugs.

This patient made a rapid recovery. By Sept. 27, 1943, he was up and about without complaints. X-ray examination of the chest was negative except for the presence of an opaque foreign body 3 by 10 mm. in size in the hilar region of the left lung. Oct. 15, 1943, he was evacuated to the rear to complete his convalescence.

No patient was operated upon for the removal of foreign bodies retained within the parenchyma of the lung as determined by anterior-posterior and lateral roentgenograms, although 26 of the 67 patients with penetrating wounds had such a complication when they were admitted to the hospital. These foreign bodies were all small, being less than 10 mm. in their greatest diameter as estimated from the x-ray film, except in two or three instances. In these exceptional cases the largest diameter varied from 10 to 15 mm. Which foreign bodies should be removed, and when, we are not qualified to say. None of the 26 patients with this complication that were observed by us presented symptoms which could be definitely attributed to the foreign body, however.

Since the exigencies of war allowed some patients to remain in the hospital only a few-days while others remained a relatively long time, no accurate impression of the proportion of soldiers with intrathoracic injuries, such as those contained in this report, that can be returned to duty in a given time is possible. Information, of course, is also lacking on how well those soldiers that were returned to duty held up to the strain of army service. Nevertheless, it is interesting to note that approximately one-fourth (20 out of 76) of the patients with serious thoracic injuries were returned to service. For only 7 of these 20 patients was a limited type of duty requested. These 7 all had penetrating wounds.

There was a total of 66 patients with penetrating wounds of the chest. Forty-eight patients with penetrating wounds were therefore evacuated to the

rear or returned to the United States as class "C" casualties. The patients placed in class "C" at our hospital numbered 11. There were 37 patients evacuated to hospitals further in the rear in North Africa. We feel certain that a number of those evacuated to the rear could have been returned to duty after a few additional weeks of convalescence and probably were so handled. We have no information, however, as to what actually did happen to any of the evacuated patients. Of the 11 patients placed in class "C" at our hospital, 3 were so classified solely because of wounds other than of the chest. In the 8 remaining cases the chest wound was the only, or one of several reasons, for placing the patient in class "C."

It may be questioned whether we were justified in returning men to duty as quickly as we did. During the early weeks that the hospital was in operation no definite criteria were followed. The decision rested entirely on the discretion and clinical judgment of the surgeon. During the latter weeks, however, after a spirometer had been constructed out of tin cans, string, and solder, vital capacities were recorded on a few patients and it was tentatively decided that despite the patient's general condition and despite the fact that all his wounds had healed, no soldier would be returned to duty unless he had a vital capacity of at least 3,500 c.c. Whether such a rule will be of help or not, future experience will have to say. Any means by which the decision to return a wounded man to the dangers and rigors of battle can be made more objective should be welcomed by all military surgeons.

Special mention should be made of the 3 patients in whom coagulation and beginning fibrosis of the intrapleural accumulations of blood occurred. Such a result occurs much more frequently than has generally been believed in the past. Thoracotomy with removal of the clot and decortication of the lung has become the accepted procedure in such cases. Two of our patients with this condition were operated upon elsewhere. The history of the third patient is reported here.

CASE REPORT

A soldier (Case 28, Table V) was struck by shell fragments, Sept. 13, 1943, near Paestum, Italy, with resulting penetrating wounds of the right arm, right knee, and left side of the chest. Fourteen hours later, at an evacuation hospital, his wounds were debrided and the abdomen explored through a laparotomy incision. The abdominal cavity was found to be normal. Two hundred cubic centimeters of blood were aspirated from the left side of the chest. One week later he was transferred to a British general hospital where frequent attempts to aspirate the chest were made. On only two occasions were sizable amounts of fluid recovered.

This patient was admitted to our hospital Oct. 4, 1943, at which time all of his wounds were found to be healed. The left side of the chest was dull to percussion, silent to auscultation, and moved very little during respiration. X-ray examination revealed opacity throughout the entire left lung field with a marked shift of the mediastinum to the right. A small opaque foreign body could be detected in the hilar region of the left lung. Several attempts at aspiration at different places in the chest yielded only small amounts of differently tinted fluid.

Oct. 11, 1943, the left seventh rib was resected and the pleural cavity opened widely. The left lung was found to be entirely collapsed and the left pleural cavity filled with an organizing hematoma which contained scattered locules of fluid. This material was all removed and a layer of organized fibrin, 5 to 10 mm. thick, was then stripped from off the visceral pleura. This allowed the lung to expand and fill the chest completely when the incision was closed. The pleural cavity was not drained, but aspirated at six, twenty-four, and forty-eight hours after operation with recovery of 75, 30, and 5 c.c. of bloody fluid, respectively. The patient made a very satisfactory convalescence, being out of bed and walking about at the end of one week. Oct. 26, 1943, he was returned to the United States for further convalescence.

SUMMARY

Eighty-one patients with intrathoracic disease and injury were treated on the Surgical Service of a United States Army General Hospital during its service in North Africa. Sixty-six of these patients were battle casualties. One patient died during operation for a mediastinal teratoma. Patients with intrapleural accumulations of blood or bloody fluid were treated by repeated thoracentesis. Seventeen patients had been subjected to primary major surgical procedures at more forward hospitals. Only one patient was so treated at our hospital. Twenty-six patients had metallic foreign bodies retained within the chest. None was operated upon at the hospital. Twenty-five per cent of all patients with intrathoracic wounds or injuries were returned to duty during their stay at the hospital. One patient with an organizing intrapleural hematoma was successfully operated upon with gratifying immediate results.

PUTRID EMPYEMA WITHOUT FOUL SPUTUM

"SURPRISE" PUTRID EMPYEMA

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PUTRID empyema usually is a complication of a putrid pulmonary abscess. Most putrid empyemas are readily recognized as such before pus is obtained and examined because they occur in patients with known pre-existent abscesses with foul sputum. In another paper* we have pointed to the frequent occurrence of empyemas complicating "shut-off" putrid lung abscesses. In those cases an abscess of substantial size is the usual precursor of the empyema. There remain instances of putrid empyema in which sputum when present is not foul and a causative pulmonary abscess is not demonstrable. We have termed these cases "surprise" putrid empyemas because they are often not recognized, and frequently not suspected, before a pleural aspiration is performed. Excluded from consideration in this paper are foul empyemas derived from subphrenic, mediastinal, or other nonpulmonary sources.

Putrid empyema without foul sputum is not to be classified as rare merely because the cases do not appear as such in the literature. They have been encountered not infrequently in our experience but only fifteen well-documented cases have been selected to form the basis of this paper.

The age and the sex incidence are of interest and each has a bearing on the subject. There were 2 women and no children. The youngest patient was 28 years of age while most were in the fifth decade.

Careful history and meticulous examination are necessary in order to discover the etiology of the pleural infection. Two cases occurred after general anesthesia for unrelated conditions. One followed tooth extraction, one after removal of tartar from the teeth, and another after tooth repair under local anesthesia. In one case there was a three-day interval between the removal of

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nasal polyps and the onset of the disease. In the other cases there were no obvious etiologic factors. In 5 of these the teeth and gums were healthy; in 6 specific mention was made that gingivodental infection existed. There were no tonsillar infections or infections elsewhere in the body; sepsis was not present. Coma or dulling of the senses other than normal sleep had not been present. The great similarity of all these facts to the situation in "shut-off" acute putrid abscesses and to a lesser degree in typical acute putrid abscesses will be pointed out later.

The clinical manifestations have been broken down into several headings:

1. Onset and Course: In 10 of the 15 cases the onset was sudden with moderately or extremely severe chest pain. This was characteristically aggravated by movement, respiration, and often by pressure on the chest and was typical, severe, pleuritic pain. In some the pain remained severe for several days and gradually tapered off but never completely disappeared. In others the pain diminished in severity rather quickly only to reappear with increasing severity. In 4 cases the pain lasted for about one week and then disappeared. In most instances, however, pain persisted until the time of operation (several weeks). In the remaining 5 cases pain was delayed for varying periods after the onset. In 1 case (see Case Reports) of chronic putrid empyema, pain first appeared about one and one-half months after the onset but persisted in mild fashion until operation about two months later.

In 10 of the 15 cases, cough was not present when the disease began. In 4 cases there was no cough at any time during the entire course. In 9 cases cough was mild or moderate and in 2 was severe, starting several days to a week or more after the pain first appeared, persisting for a varying time often until the postoperative period and then diminishing. In 3 cases cough was present from the onset. In only 2 instances was the cough severe. Both of these patients had bronchiectasis probably unrelated to the empyema.

Absence of significant amounts of expectoration parallels that of cough. In 4 there was no sputum; in 3 there was scant expectoration for a few days; in 4 scant expectoration lasted for one week or longer, and in the remainder moderate amounts were brought up for longer periods. Streaks of blood were unusual; hemoptyses did not occur; foulness was never present. The sputum was either mucoid and saliva-like or mucopurulent.

Nine of the 15 patients were moderately or severely and critically ill at, or shortly after, the onset. In one the onset was mild but the symptoms became severe after one week. The other 4 cases presented pictures of relatively mild illness at the onset and throughout the course. In these the patients were ambulatory for varying periods after the inception of disease and the temperature ranged between 100 and 102° F.

2. Physical Examination: The presence of fluid in the pleural cavity was suspected in most cases on admission. The general appearance of critical illness was often present. Dyspnea or tachypnea and cyanosis were present in about three-quarters of the cases. The condition of the teeth and gums was mentioned under etiology. When the pleural fluid was situated between the parietal pleura and the lung, dullness to flatness and diminished to absent fremitus and breath sounds were the usual findings. With the fluid in an unusual location as subsequently ascertained (intrapulmonary, interlobar, or paramediastinal), the findings were confusing and difficult to interpret. Tenderness of the chest wall was extreme in several cases. Clubbing of the digits was encountered only three

times in this series. In 4 instances the pleural fluid and air accumulated so rapidly and in such large volume that displacement of the trachea and mediastinal structures occurred.

3. Physical examination of the chest has been relegated to a subsidiary position as roentgen aid to diagnosis has developed. The roentgenographic appearance in these cases of putrid empyema was that of localized or more widespread collections of fluid with or without the presence of air. In some the initial appearance suggested a simple effusion. This was due usually to the outpouring of sterile sympathetic fluid as was shown in a number of the cases by aspiration of the chest. Later in the course, with the persistence or sudden reappearance or exacerbation of the chest pain, the picture was often quite different. Thus, a putrid pyopneumothorax was frequently disclosed representing a rupture of the pulmonary abscess into the pleural cavity. The roentgenographic picture may change suddenly. Any new incident such as cessation of cough, reappearance of pain, sudden rise in temperature, or increase in prostration should be checked with a film. A simple effusion may be transformed into a pyopneumothorax. The x-ray appearance may differ but little from, or be identical with, that of "shut-off" putrid pulmonary abscess with empyema described in another paper. An underlying pulmonary abscess was never demonstrable roentgenographically in this series. The difficulties mentioned elsewhere in interpreting correctly the shadows due to loculated intrapulmonary, interlobar, or paramediastinal pyopneumothoraces pertain also to these cases.

4. In order to convey a picture of the difficulty of diagnosis, reference should be made to the number of chest aspirations that were resorted to in these cases before foul pus was obtained. In only 3 cases did the first chest aspiration in the hospital reveal foul pus and in all there was present an unusually widespread putrid pleural infection. In the other cases an average of four chest aspirations each was required before foul pus was obtained and the diagnosis established. One or more of three reasons can be invoked to explain the repetition of aspiration which was necessary before pus was obtained: (1) Inaccurate roentgenographic localization of the pleural collection, (2) sympathetic effusions which often preceded and masked the underlying putrid infection, (3) unusual situation of the empyema which is characteristic of many of these cases. We can add here the fact that the collection of foul pus may not only be situated at a point away from the surface but also may be small. Hence, whenever a putrid empyema is suspected (not in obvious cases) aspiration should be performed in the operating room and the needle left in place for the operative procedure. There have been not a few instances in which great difficulty has been experienced in the operating room in finding foul pus which previously had been revealed by aspiration.

5. Closely related to the number of chest taps is the delay which occurred from the time of hospital admission both in ward and private patients until the true nature of the pleural infection was ascertained. Excluding those cases in which a chest tap on admission revealed foul pus, there was a delay of seventeen days, on the average, from admission to diagnosis and operation. When to this is added two- to three-week periods or longer (one case three months) during which time patients remained at home or in another hospital, evidently it has taken long periods in most cases for the diagnosis to be established. We will indicate later that most of these patients were considered to have some other intrathoracic disease throughout most of the clinical course.

6. The treatment of putrid pleural infections is always surgical. The details of the operative procedure of drainage of these putrid empyemas will not be given here. Some basic considerations are:

A. Before rib resection is undertaken, an aspirating needle should be in situ in the empyema. This will enable the operator to locate the putrid infection. The exception to this is a situation in which foul pus has been found previously, but cannot again be reached by an aspirating needle on the operating table. Cautious search must then be made after a portion of a rib has been excised.

B. In critically ill or moribund patients in whom large empyemas exist, local anesthesia is imperative and in rare instances only preliminary intercostal tube drainage is permissible. This may so improve the patient's condition that a more extensive procedure can be undertaken later.

C. In other patients, one or more ribs are excised to provide adequate access. The contents of the empyema cavity are evacuated by suction and sponge. The full limits of the cavity are ascertained. Occasionally, counter-drainage of the cavity will be necessary. The entire space is packed lightly with iodoform gauze. It is important to incise and excise the tract of the aspirating needle that penetrated the empyema in order to obviate a phlegmon of the chest wall. The visceral pleura is inspected for a lung abscess.

7. Following these principles the operation disclosed empyema cavities of various sizes, filled and covered by a shaggy necrotic foul exudate. In a few cases a lesion could be discerned in the pulmonary parenchyma but in none was a lung abscess found at operation. A blowing bronchial fistula was demonstrated at operation in only 1 case. In 1 case the empyema cavity contained about 100 c.c. of pus; in 6 cases between 200 and 300 c.c. was found; in 6 instances up to 1 liter was present and in the remaining 2 the lung was completely collapsed and approximately 2 liters of fluid were removed. The empyema cavities were usually of bizarre shapes. Extensions from the main cavity to form narrow tracts or tongues were not infrequent. Special technical problems often arise because of the relatively frequent occurrence of interlobar, paramediastinal, or intrapulmonary collections.

8. The postoperative course usually was smooth and convalescence was rapid when adequate drainage and exposure of all the recesses of the empyema were carried out. There were 3 deaths in the series of 15 selected cases due essentially to delay in diagnosis. One occurred in a patient who had been at home for three weeks after the onset, treated as a case of myocardial infarction. Autopsy performed two weeks after drainage of the putrid empyema failed to disclose any evidence of a residual putrid infection. The heart and coronary arteries were relatively normal. Death was due to bronchopneumonia. Another patient was treated at home for two weeks for lobar pneumonia. On admission to the hospital, she had a total putrid pyopneumothorax which was drained. The cause of death was a putrid mediastinitis and pericarditis. The third case was a 70-year-old patient who was treated under a mistaken diagnosis of myocardial infarction, pneumonia, and pleural effusion. Eighteen days after the onset, the fluid was withdrawn in order to relieve respiratory embarrassment. The operator was greatly surprised to obtain foul pus. Despite adequate operative drainage at this late date, the patient eventually succumbed to a nonputrid bronchopneumonia. At autopsy there was no evidence of a putrid empyema, lung abscess, or myocardial infarction.

Most of the patients showed improvement within several days after drainage. Depending upon the previous duration of disease and the ease of exposure of recesses, the temperature was normal after one to two weeks. The empyema cavities became clean in a few days. In 3 of the 15 cases a transient bronchial fistula was noted in the first or second week after operation.

The differential diagnosis of these "surprise" or "silent" putrid empyemas was often difficult. The diagnosis should always be entertained whenever an adult presents the features which have been described. When the suspicion is aroused, the aspirating needle will provide the evidence that a putrid infection exists. Aspiration of foul fluid or air is the only means by which the diagnosis can be made in these cases. On the other hand, aspiration has its dangers and must be employed carefully and with roentgenologic control. A list of the diagnoses which were entertained before the correct diagnosis was made will indicate the difficulties which were present: lobar pneumonia, bronchopneumonia, bronchiogenic carcinoma, pleural effusion, nonputrid empyema, peripheral type of pulmonary carcinoma, actinomycosis of the lung, and tuberculosis.

What is the evidence that putrid pleural infections which fit into the syndrome described are due primarily to a ruptured acute putrid pulmonary abscess?

By reference to the clinical data of "shut-off" putrid lung abscess in another paper, one will be struck by the great similarity between them and the ones detailed here. When a "shut-off" putrid lung abscess implicates the pleura and is complicated by a putrid empyema, its clinical picture may be identical with that of "surprise" putrid empyema described in this paper. There is the same prominence of severe prolonged chest pain and the same de-emphasis on cough and expectoration. The cases may be similar clinically; they respond to the same therapy. Then, there are the cases of putrid empyema, in which an abscess cannot be demonstrated unequivocally, in which a shallow depression in the visceral pleura may be observed at operation. These depressions may represent the sites of ruptured lung abscesses. Reference should be made to those cases in which a lung abscess has not been demonstrated but in which a bronchial fistula was noted during the postoperative course. Such a fistula, even when open for a short time, must indicate dissolution of pulmonary tissue and the related bronchus, presumably a lung abscess. The cases in which there is good reason to believe that some pulmonary lesion did exist differ in no way from the other cases of putrid empyema in which such evidence is lacking. The entire group bears a strong clinical resemblance to "shut-off" acute putrid pulmonary abscess with empyema.

We have become convinced, after careful observation at operation of these and other cases, that the size of ruptured "shut-off" putrid abscesses with empyema is not the same as before rupture. It is very likely that putrid contamination of the pleura occurs only by actual and fairly free rupture of the pulmonary lesion. At times we have been able to see abscesses with their roofs blown off, so to speak. At other times a bead or large droplet of pus on the visceral pleura may indicate the presence of an underlying abscess. When the rupture occurs, it appears that in certain instances the abscess tends to collapse. When such an abscess is opened surgically, numerous fairly large bronchi may be found in the wall. This can be interpreted as showing that the volume of pulmonary tissue originally involved was large. Considerations and observations of this type lead us to expect a diminution in the size of a putrid lung abscess when it has spread to the pleura; that is the abscess collapses after rupturing.

Roentgenographic studies afford other evidence of the existence of bronchopleural communications in some of the cases of "surprise" putrid empyema. Such communications can be interpreted as showing the previous presence of a lung abscess. On several occasions, we have observed the accumulation in the pleural cavity of large quantities of air in a matter of a few hours. The successive roentgen observations in such cases reveal the transformation of small pleural effusions into pyopneumothoraces. Even if the bacteria in putrid infections were gas producers, it is inconceivable that 1 liter or more of gas could be generated within a period of several hours. Since we have never observed gas in a putrid abscess in a location in which entrance of air from the outside could be excluded, we believe that the bacteria involved in such an infection are not gas producers within the human body. We interpret the fluid levels observed in hydro- or pyopneumothoraces as evidence of bronchopleural communication and indirectly of a pre-existent lung abscess.

Finally it must of course be assumed, in the absence of other sources, that the pleural infection was derived from the lung, either a pulmonary abscess or a gangrenous bronchopneumonia. If an underlying pulmonary suppurative focus is not postulated as the cause, one must assume seepage into the pleura from a pulmonary lesion of whose existence there is no acquaintance.

CASE REPORTS

W. W. (Hospital No. 431467), was a 46-year-old man whose admission was antedated by a three-month history of malaise, low-grade fever, sweating, and a mild cough. Two months before admission he had a small hemoptysis and this represented about all the expectoration. About one and one-half months before admission he experienced sudden, severe, sharp pain in the right side of the chest, which subsided somewhat in the next few days but persisted mildly until admission.

He was well nourished. Marked pyorrhea alveolaris and clubbing of the fingers were present. Physical examination of the chest revealed a circumscribed area of flatness over the right upper posterior part of the chest and roentgenographically this was a homogenous, fairly dense, well-delimited shadow whose nature was not clear. At bronchoscopy, a slight amount of thin, nonfoul, nonrecurring secretion was noted from the right upper lobe bronchus. Aspiration of the pleural cavity was attempted on five occasions and was unsuccessful. Two weeks after admission, after a course of three and one-half months of low-grade chronic illness, a chest aspiration revealed typical foul fluid.

Immediate operation through the last needle tract disclosed an exceedingly thick-walled flat putrid empyema. A definite communication with pulmonary parenchyma could not be demonstrated. The empyema was opened widely and all recesses were packed lightly.

The cavity diminished in size rapidly and the patient became asymptomatic. Two months after operation the wound was completely healed and the patient was asymptomatic. At follow-up examination two years later the patient was well.

This is an unusual case of chronic putrid empyema without evident underlying putrid lung abscess. The prolonged chest pain, mild cough, and absence of sputum are typical.

L. J. (Hospital No. 393858), a 29-year-old man, had a tooth filled under local anesthesia, two weeks before admission. One week before admission he experienced sudden, severe, stabbing pain in the left lateral part of the chest. This continued until admission. There was no cough or expectoration. Low-grade fever and moderate weakness were present.

Examination revealed an acutely ill patient. There was dullness and diminished breath sounds over the left lower lobe. Clubbing of the digits was not observed. At no time was there any expectoration and slight cough was present for only one day. The temperature varied between 102 and 104° F. and the chest pain diminished gradually. X-ray examination on several occasions revealed a small amount of fluid at the left base. Fourteen days after the onset the beginning of clubbing of the digits was observed. Two aspirations of the chest failed to disclose foul fluid but the third, twenty days after the onset, revealed foul pus.

One liter of thin putrid pus was evacuated at operation. It was situated paravertebrally. A primary pulmonary source was not seen. The postoperative course was smooth; the cavity

became clean in about one week and all symptoms disappeared. A bronchial fistula did not appear. Three months after discharge the wound was healed and the patient was asymptomatic at follow-up examination four years later.

This is the typical sequence in a case of putrid empyema in which a pulmonary source was never demonstrated. It is assumed that a small acute putrid lung abscess ruptured early in the course and was responsible for the empyema.

J. E. (Hospital No. 486600), a 70-year-old man, became ill three days before admission with sudden, severe, pain in the left anterior part of the chest, cough, temperature to 101° F., and dyspnea. He had had a moderately severe productive cough for many years.

He was acutely ill, dyspneic, orthopneic, and cyanotic. The heart was enlarged and the sounds were of poor quality. Gallop rhythm was present. There was a diminution in breath sounds and tactile fremitus over the left lower lobe. The pain continued for several days and then subsided. The cough was moderately severe and productive of several ounces of nonfoul mucopurulent sputum daily. The temperature varied irregularly between 100 and 101° F. A course of sulfadiazine was without effect on the clinical state. Repeated electrocardiograms were bizarre and suggested recent infarctions of the anterior and posterior surfaces of the heart. Because of a persistence and increase in the signs of fluid in the pleural cavity, roentgenographic examination was first performed ten days after admission. It revealed a localized pleural collection of fluid in the lower two-thirds of the left side of the chest. Aspirations of the chest on the eleventh, thirteenth, and fifteenth days after admission revealed large quantities of clear, nonfoul fluid (sympathetic effusion). The following day thick, green, foul pus was obtained by aspiration in the eighth intercostal space in the midscapular line.

Operation was performed at once, 300 c.c. of foul pus being evacuated from the pleural cavity. The walls of the empyema cavity were markedly thickened. Neither a lung abscess nor a bronchial fistula was observed.

During the remaining three weeks, the patient had an irregular temperature as high as 102° F. He continued to cough moderately, but the sputum was not foul. The operative wound became clean in several days and the foul odor disappeared. Shortly before death, signs of a pneumonia in the right lower lobe were observed.

Autopsy examination revealed cylindrical, nonputrid bronchiectasis and pulmonary fibrosis in the left lower lobe, nonputrid bronchopneumonia in the right lower lobe, pulmonary emphysema and coronary artery sclerosis with scattered myocardial fibrosis but no evidence of a myocardial infarct. The putrid pleural disease was no longer present.

This case illustrates the dangers of an undiagnosed putrid empyema. Roentgenographic examinations and pleural aspirations earlier in the course might have facilitated prompt diagnosis. Earlier operation might have prevented the fatality. The clinical history was confused by the bronchiectasis, severe cough, and copious sputum, all of which were essentially unrelated to the putrid empyema.

SUMMARY

The diagnosis of putrid empyema in the absence of foul sputum or other evidence of a pulmonary abscess is difficult. The lesion should be suspected and efforts at diagnosis persisted in when a given set of clinical manifestations are present. Prolonged delay in diagnosis may be fatal. The variable clinical manifestations are described. They consist primarily of outstanding and persistent chest pain, slight cough and expectoration, and an illness which is severe at least in the initial stage. Cough may be absent; the course may be chronic. The discovery of foul pus by aspiration of the pleura is the sole method of establishing the diagnosis. This disclosure will often be a surprise. Wide drainage of the main lesion and its ramifications will effect a cure unless the diagnosis has been delayed too long. Although a pulmonary abscess is not demonstrable, we believe, for reasons which have been advanced, that a putrid pulmonary abscess is the precursor of "surprise" putrid empyema. Résumés are presented of 3 of the 15 cases on which the paper is based.

PULMONARY EMBOLISM IN FRACTURES OF THE HIP

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CONSIDERABLE effort has been expended upon the mechanical correction of the osseous deformity in fractures of the hip for many generations, but little study has been given to the actual cause of the complications following this injury. Inadequate investigation is responsible for the marked discrepancy in the mortality figures from different institutions and in the clinical impressions of the causes of death. Therefore, we undertook a careful analysis of our own cases that came to autopsy in order to evolve, after a better understanding of the *modus operandi* of death, some means to reduce our mortality rate.

At the Queens General Hospital, 304 patients with fractures of the hip were treated from 1935 to 1944, with 86 deaths, a mortality of 28 per cent. Two-thirds of the deaths occurred in the group between 70 and 80 years of age. Findings in 25 autopsies were exceedingly illuminating. Investigation of the deaths revealed that 9 cases were due to pulmonary embolizations, 8 to bronchopneumonia, 3 to arteriosclerotic heart disease, 1 to hemorrhage from a duodenal ulcer, 1 to sepsis from a wound infection, 1 to sepsis from a severe purulent prostatitis, 1 to pyelonephritis, and 1 to voluntary starvation in a demented woman. Thus, 68 per cent of the necropsies exhibited pulmonary complications; of which 53 per cent were proved pulmonary emboli. The remaining 47 per cent were reported as bronchopneumonia; many of these cases were, possibly, the result of minute embolizations with secondary pneumonitis.

The high incidence of pulmonary embolizations prompted us to undertake a study of the factors that influence the pathogenesis. Venous thrombosis in the lower extremities has been established as the primary source of pulmonary emboli by Roessle,¹ Frykholm,² Bauer,³ and other investigators. The sites of venous thrombosis in their relative order of frequency, as described by Frykholm,² occur in the veins of the calf muscles, the posterior tibial, the peroneal, the popliteal, and the veins of the adductor muscles, because damage to the intima of the vein is greatest in these regions. He stated, that under normal conditions, erect posture results in the distention of the lower extremity veins by the column of blood that they support. These veins become collapsed when the horizontal position is assumed. When a patient is confined to bed, the collapse of the calf vein is aggravated as the result of a compression force exerted against it by the resistance of the underlying mattress. In this manner, intima is pressed against intima. Continued pressure causes damage to the endothelial cells, because the nourishment provided to them by the sluggish stream of blood is inadequate. The injured cells liberate a thromboplastic substance which favors local thrombosis. The most frequent site of thrombus formation occurs at the valve structures because the lumen of the vessels is narrowest at these points, and the valves, acting as weirs, produce an eddy formation with the deposition of platelets.

An individual who suffers a fracture of his hip presents ideal conditions for the development of venous thrombi in the lower extremities. The blood

TABLE I. PRESENT SERIES

Total patients treated	304
Total deaths	86
Total autopsies	25
Pulmonary complications	16
Nonpulmonary complications	9

stream is slowed by the complete voluntary immobilization of the extremities to avoid painful movements at the fracture site, by the associated reflex vasospasm induced by the fracture, and by the impaired cardiac circulation and the inadequate peripheral circulation of this age group. Concomitantly, changes in the chemical composition of the blood conducive to thrombosis formation result from the liberation of tissue ferments by the lacerated muscles, ligaments, and bone at the fracture sites. Intimal damage occurring when the patient is bedridden is

TABLE II. RÉSUMÉ OF TWENTY-FIVE AUTOPSIED CASES STUDIED

CASE NO.	PATHOLOGIC DIAGNOSIS	SITE OF FRACTURE	AGE (YR.)	TYPE OF TREATMENT	AMBU-LANT STATUS OBTAINED	TREAT-MENT STARTED DAYS AFTER AD-MISSION	ILLNESS STARTED DAYS AFTER TREAT-MENT	TOTAL NUMBER DAYS IN HOSPITAL
1	Pulmonary embolism	Intertrochanteric	80	Smith-Petersen nail	No	4	1	14
2	Pulmonary embolism	Neck	80	Wilkie boots	Yes	11	1	42
3	Pulmonary embolism	Subtrochanteric	80	Sandbags	No	1	27	27
4*	Pulmonary embolism	Intertrochanteric	78	Smith-Petersen nail	No	7	1	8
5	Pulmonary embolism	Intertrochanteric	72	Russel traction	No	1	25	70
6	Pulmonary embolism	Neck	70	Smith-Petersen nail	No	9	Immediate	9
7	Pulmonary embolism	Intertrochanteric	70	Wilkie boots	No	1	11	20
8	Pulmonary embolism	Intertrochanteric	65	Wilkie boots	No	1	5	6
9	Pulmonary embolism	Subtrochanteric	54	Russel traction	No	14	3	16
10	Bronchopneumonia	Intertrochanteric	88	Russel traction	No	10	8	18
11	Bronchopneumonia	Neck	79	Sandbags	No	1	4	4
12	Bronchopneumonia	Intertrochanteric	78	Wilkie boots	No	1	11	14
13	Bronchopneumonia	Intertrochanteric	76	Wilkie boots	Yes	10	46	58
14	Bronchopneumonia	Intertrochanteric	75	Sandbags	No	1	1	8
15	Bronchopneumonia	Subtrochanteric	67	Russel traction	No	1	8	10
16	Bronchopneumonia	Intertrochanteric	65	Wilkie boots	Yes	7	10	20
17	Arteriosclerotic heart disease	Intertrochanteric	63	Sandbags	No	1	1	2
18	Arteriosclerotic heart disease	Subtrochanteric	63	Russel traction	No	1	1	1
19	Arteriosclerotic heart disease	Neck	60	Sandbags	No	1	16	18
20	Arteriosclerotic heart disease	Intertrochanteric	55	Russel traction, body spica	No	1	39	50
21	Sepsis, wound infection	Intertrochanteric	79	Smith-Petersen nail	No	2	6	31
22	Sepsis, purulent prostatitis	Intertrochanteric	73	Sandbags	No	1	2	6
23	Sepsis, pyelonephritis	Intertrochanteric	61	Wilkie boots	No	2	4	10
24	Hemorrhage, duodenal ulcer	Intertrochanteric	72	Russel traction	No	1	30	37
25	Starvation, voluntary	Neck	78	Russel traction	No	1	1	78

*Concomitant basilar artery thrombosis.

enhanced when spicas or Wilkie boots are utilized because of the greater pressure exerted against the calf veins by these plaster of Paris encasements.

The most dangerous type is the silent propagating thrombus, described by Ochsner⁴ under the term "phlebothrombosis," because due to the lack of local symptoms, no precautions are undertaken. This insidious silent propagating venous thrombus was predominant in our series; not one patient gave any symptoms referable to the presence of venous thrombosis in the lower extremity. As a rule, some effort motion discharged the fatal pulmonary embolus; in one case manipulative reduction in the operating room; in another, transfer of the patient from a bed to wheel chair; in others, turning the patient from one side to the other in bed. Deaths occurred as early as the sixth day and as late as the seventieth day following injury.

The pathologic anatomy and the clinical course of pulmonary embolizations depend upon the size and the sterility of the embolus. Four of the nine fatal cases of pulmonary embolization resulted from massive emboli to the pulmonary conus, the pulmonary artery, or one of its branches. The patient was described as seized suddenly with severe pain, dyspnea, and cyanosis. A state of shock occurred rapidly, and death ensued in a few to thirty minutes. Pathologic examination of the lungs revealed little gross change, because death had been too rapid.

TABLE III. CLINICOPATHOLOGIC STUDY (CASES OF PULMONALY EMBOLISM)

CASE NO.	NUMBER OF ATTACKS	TYPE OF DEATH	TYPE OF EMBOLUS	PULMONARY PATHOLOGY
9	One	Sudden	Massive	Normal
8	One	Sudden	Massive	Normal
6	One	Sudden	Massive	Normal
3	One	Sudden	Massive	Normal
2	Multiple	Slow decline	Bilateral small	Bilateral infarcts
7	Multiple	Slow decline	Bilateral small	Bilateral infarcts
5	Multiple	Slow decline	Bilateral infected	Bilateral infected
1	None	Slow decline	Bilateral minute infected	Multiple small abscesses
4*	None	Sudden	Bilateral minute	Bronchopneumonia atelectasis

*Concomitant basilar artery thrombosis.

Three of the nine cases had clinical evidence of previous attacks of pulmonary embolization. Episodes of chest pain, dyspnea, and cyanosis occurred, which disappeared spontaneously after a few days. The patient was left with a residual weakness; this weakness is apparently a most important sign. At autopsy, emboli to the smaller branches were demonstrated which were associated with the formation of infarcts of the lung. The relative age of each infarction was determined by studying its structure and that of the corresponding adherent pulmonary embolus.

Two of the nine cases showed multiple minute emboli which occluded some of the smaller radicles of the pulmonary artery. These embolizations were not evidenced by any clinical signs or symptoms. Multiple embolic abscesses of the lungs and resultant sepsis were present in one case. A bilateral bronchopneumonia attended the other; the immediate cause of death in this case was a basilar artery thrombosis. The cases may be looked upon as incidental pulmonary emboli. The thrombi are too small, and the collateral circulation is sufficiently adequate to prevent an infarction. Small emboli become significant only when they are septic from infected veins, and produce multiple lung abscesses.

Sudden death from pulmonary embolism has been studied by Horn, Dack, Friedberg⁵ and others; they found that one of two patterns may result. Complete or almost complete obstruction of both pulmonary artery branches, or the pulmonary conus due to a massive embolus, is fatal within a few minutes. Death results from asphyxia; the entire circulation of blood in the pulmonary artery is occluded. The right side of the heart in a few cases is dilated and the peripheral veins and organs show congestion. When emboli are too small to produce complete occlusion of the pulmonary artery, a superimposed spasm may complete the obstruction. Solitary embolization to either of the branches of the pulmonary artery may precipitate death by stimulating afferent vagal fibers with resultant vago-vagal reflex spasm of the coronary arteries and the bronchi, with severe cardiac inhibition.

Clinically, the diagnosis of the true cause of death was made in but one case of the nine patients that succumbed to pulmonary embolization, and this was entertained because of the sudden death of the patient. In all of the others, the clinical impression varied from bronchopneumonia to heart disease. This large diagnostic error may be due to the inability of the physician to examine the patient properly for Homans' dorsiflexion sign, tenderness of the calf muscles, cyanosis of the skin, and edema of the extremities. Particularly is this true when the plaster of Paris cast masks all local manifestations. On the other hand, physicians may not be cognizant that thrombosis of the calf veins is a frequent complication of fractures of the hip and, therefore, are not sufficiently vigilant.

Adequate efficient therapy for the prevention of embolism must be the desideratum if the mortality rates are to be lowered. Venous thrombosis occurs rarely when manipulative operative procedures are instituted early. These methods encourage ambulatory care of the patient, and the stasis of blood in the lower extremities and the pressure upon the calf region are to a large extent eliminated. Many of the patients in our series, in whom fatal embolization occurred, were confined to bed for a period of four to twelve days before any operative or manipulative procedure was done. This period of procrastination allows for venous thrombosis in the lower extremities. In fact, one case of massive embolization occurred while a reduction of the hip was being effected on the ninth postadmission day. Therapy included nailing in three cases, Russell traction in two cases, Wilkie or well-leg traction in three cases, and sandbag immobilization in one case. Eighty-eight per cent of the patients were bedridden not through choice, but because conditions beyond the control of the surgeon precluded mobilization of the patient. Thrombosis and embolism occurred in such cases because the patient did not actually obtain ambulatory status despite operative treatment to effect it.

Recent literature has been much concerned with the use of anticoagulation therapy in the form of dicumarol and heparin. Under such treatment, thrombus formation in veins can be prevented, and in the case of venous thrombosis, propagation of the original thrombus limited. Thrombosis and fatal embolization may occur after the drug has been discontinued. Since the treatment of fractures of the hip necessitates prolonged hospitalization and immobilization, a course of anticoagulation therapy must be continued over a period of months. This form of treatment not only becomes expensive, but also detrimental to the morale of the patient since it requires constant vigilance and venepuncture.

Venograms or phlebograms as a diagnostic method to discover venous thrombosis at its inception is not applicable to fractures of the femur. In those

cases where application of plaster of Paris casts are used in the form of a spica or Wilkie boot, x-ray will not demonstrate the passage of the opaque dye in the veins of the leg and foot because of the overlying opacity. Allen and associates⁶ have produced data which seems to establish the unreliability of a phlebogram, since they have demonstrated positive clinical evidence of a thrombus with a negative phlebogram in one-third of the cases they studied.

To decrease the incidence of massive pulmonary emboli, early prophylactic venous ligation should be effected in patients who cannot have early operative and ambulatory treatment. Our mortality and morbidity may be diminished since many cases of pneumonitis may be the result of small pulmonary embolizations. Widespread interest has followed Homans' contributions to the procedure of ligation of the femoral vein as a prophylactic measure for pulmonary embolization in cases of venous thrombosis of the lower extremity veins. Allen and co-workers⁶ ligated in 202 patients up to January, 1943, with no mortalities; 60 per cent of his patients were over 50 years of age. They reported no occurrence of fatal embolization following ligation. They have demonstrated that the earlier the vein is ligated, the smaller the clot found and the less swelling of the leg results. Perhaps ligation of a normal femoral vein prophylactically may avoid edema in the lower extremities.

Venous ligation is not an emergency procedure. Ligation should be done within the first three days after the accident, as soon as shock is completely overcome. The site of election is the superficial femoral vein. Allen and associates⁶ have demonstrated the necessity for bilateral venous ligation, because more often than not thrombosis may occur in the deep veins of both lower extremities. Following the ligations, the lumbar sympathetic block described by Leriche and Kunlin¹³ and popularized by Ochsner and DeBakey¹⁴ would overcome the vasospasm, enhance the collateral venous circulation, and minimize the incidence of edema. Then, the treatment of the fractured hip may be instituted at any time convenient for the correction of the disability without the fear of pulmonary embolization.

CONCLUSIONS

1. Fatal pulmonary embolization from venous thrombosis in the veins of the lower extremities is the most frequent cause of death in cases of fracture of the hip.
2. Venous thrombosis and embolism are less frequent in patients who are made ambulant early.
3. Prophylactic bilateral superficial femoral vein ligation combined with lumbar sympathetic block is suggested as most ideal for the prevention of pulmonary embolism in fractures of the hip; especially, in those who cannot be made ambulant early.

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THE TREATMENT OF PROGRESSIVE BACTERIAL SYNERGISTIC GANGRENE WITH PENICILLIN

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INTRODUCTION

PROGRESSIVE bacterial synergistic gangrene is now accepted as a clinical entity. Its underlying causes are known, its mode of onset is understood, its bacterial synergistic etiology has been repeatedly confirmed, and its characteristic appearance after it has become established should be unmistakable. Cullen,¹ in 1924, was the first to give a comprehensive case report of this condition, although at least one authentic case had appeared in the literature before that time.² Since Cullen's publication, there have been almost 100 reports of typical cases. Stewart-Wallace³ gave an excellent review with bibliography of thirty-seven cases up to 1935 and Dodd, Heekes, and Geiser⁴ continued the story, totaling eighty-six cases up to 1939. Not included in their review, there have been summaries or case reports by Pergola and Rosenfeld⁵ in 1938, by Hulten,⁶ by Ducrey,⁷ and by Touraine and Duperrat⁸ in 1939. Later, reports appeared by Antonioli,⁹ by Brodie and Bouck,¹⁰ by Constantinescu and Vasiliu,¹¹ by Mester,¹² by Vier¹³ in 1940, by Lichtenstein¹⁴ in 1941, by Gurruchaga and Manzoni,¹⁵ by Paulino,¹⁶ by Vara-Lopez¹⁷ in 1942, by Neary and Rankine¹⁸ in 1943, by Davison, Sarnat, and Lampert,¹⁹ and by Leonard²⁰ in 1944.

While some of the authors quoted in these reviews confused this disease with the chronic undermining, burrowing (nongangrenous) ulcer, the great majority have presented authentic cases. Undoubtedly many other cases have been observed and have not been included or have not been reported. One of us (F. L. M.) has reported one such case not included, besides the five mentioned in the list,²¹ and has seen and studied eight others which have not been reported at all, in addition to the three cases which are the subject of this paper—seventeen in all, and in every one of these cases the essential organisms have been found. Obviously it is not as rare a disease as was once thought and it should be recognized much more readily than it is.

One of us (F. L. M.), in 1926, found the essential bacterial agent to be a microaerophilic nonhemolytic streptococcus which was present in pure culture in

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the advancing periphery of the lesion in one of the cases described by Brewer and one of us (F. L. M.)²² This organism was associated with a hemolytic *Staphylococcus aureus* in the gangrenous margin. The combination of the streptococcus and the staphylococcus was shown to produce in animals a gangrenous lesion simulating to a degree the process in human beings. This lesion could only be obtained when the organisms were combined and not when they were inoculated in pure culture, thus demonstrating their synergistic action. This synergistic action was clearly confirmed in a later case, thus justifying the name "progressive bacterial synergistic gangrene."²³ Those who doubt this etiology have given altogether too much credit to those bacteriologic reports which included no anaerobic technique, for the microaerophilic nonhemolytic streptococcus can be found only by careful anaerobic methods. It forms a tiny colony on the anaerobic plates and is readily overgrown by such organisms as *Bacillus proteus*, *Escherichia coli*, or staphylococci.²⁴ It is hard to understand why anaerobic procedures are so often neglected in the analysis of surgical infections. Any chronic infection is subject to secondary contamination so that many organisms have been found associated with this lesion, but the consistent finding of the microaerophilic nonhemolytic streptococcus in pure culture in the spreading periphery of the lesion almost certainly establishes it as the essential causative organism. In the necrotic and the necrobiotic zones, however, it is invariably associated with staphylococci and frequently with other organisms as well.

The development of the lesion follows a definite course. It usually begins around tension sutures placed in a wound of the abdominal wall or chest which has been made for the purpose of draining either an intraperitoneal or intrapleural abscess. Frequently the intrapleural infection has developed secondary to a lung abscess of the putrid variety. The skin around the tension suture first becomes red, swollen, and tender and takes on a dusky appearance resembling a carbuncle with a slowly developing necrosis of the skin. This frequently occurs about ten to twenty days after the wound has been made. Removal of the tension sutures at that time does not control the infection which steadily spreads in all directions from the central point and gradually produces an ulcer. The lesion is usually exquisitely tender and also painful and not infrequently the entire disposition of the patient changes as the infection progresses, in spite of all the doctor can do for it.

As the ulcer spreads, the destruction of tissue is seen to be very superficial. The gangrenous skin dissolves away at its inner margin which is slightly undermined, but at the periphery of the gangrenous zone it is intimately adherent to the surrounding skin which, however, has a dusky appearance of impending death and is raised from one-half to one centimeter above the normal surface of the skin. The inner margin of this raised zone is dark purple in color and has an irregular crenated appearance. Beyond the raised, swollen area, there is a zone of erythema which may vary in width from 5 or 6 mm. to 4 or 5 cm., the outer margin gradually fading off into normal skin.

If early treatment is not instituted and the ulcer continues to grow, granulations develop in the center, and residual islands of epithelium may form a thin epithelial surface. As time goes on, the progress gradually slows down but it does not stop. It goes on inexorably in spite of any local application which the ingenious surgeon may devise. Frequently surgeons have attempted to trim away the dead tissue but almost invariably, in the past, without a radical removal of the whole lesion well beyond the zone of erythema, there has been a recurrence of the infection and a redevelopment of the characteristic marginal zones. In the past, the only cure for this condition has been com-

plete and wide excision. Then a number of different antiseptics have been applied to minimize the chances of a recurrence. Zinc peroxide has been the most effective we have tried in preventing recurrence after the excision because the microaerophilic nonhemolytic streptococcus is susceptible to it and that is the organism which has to be stopped if the lesion is to be cured. But without excision, neither zinc peroxide nor any other external application has been able to halt the steady advance of the organisms which we know to be active in the periphery of the lesion, and heretofore no medication has been able to halt their advance from within. The sulfonamides have not been effective in controlling this condition, but with the advent of penicillin, a new agent has been found which may not only prevent a recurrence after the excision, but may obviate the necessity for excision by halting the progress of the lesion and permitting a spontaneous separation of the slough. This has been demonstrated very strikingly in two patients whom we have recently treated and whose case records are reported herewith. In a third patient with multiple lesions, although it was of definite benefit, it was not quite equal to the situation, probably because the penicillin was inactivated by secondary contaminants.

CASE REPORTS

CASE 1 (Jewish Memorial Hospital No. 35114 and 40989).—N. W., aged 67 years, was admitted Feb. 15, 1944, and discharged June 25, 1944 (under the care of S. T. F.).

History.—One week prior to admission, the patient was suddenly seized with a chill, a fever of 103° F., and a cough with yellowish sputum. On the day of admission, he complained of pain in the left side of the chest.

Physical Examination.—The patient was an emaciated, old man who appeared acutely ill. There were dullness, bronchial breathing, and râles over the left lower lobe. The heart sounds were muffled and distant. X-ray films revealed an irregular bronchopneumonia throughout the left lower lobe with signs of old tuberculosis in the left apex and hilus. There was a small amount of fluid in the costophrenic angle.

Course.—Sulfadiazine was begun with a dosage of one gram every four hours and an equivalent amount of sodium bicarbonate. There was no apparent response to chemotherapy and the sulfadiazine was discontinued at the end of one week when hematuria appeared. Gradually a breakdown of lung tissue occurred in the upper part of the left lower lobe (see Fig. 1). The sputum became profuse but not foul smelling. By the end of the fifth week, the pleural effusion had increased considerably and several fluid levels were seen indicating localized pockets containing gas. Expectoration then brought forth greenish-yellow, foul-smelling pus.

A rib was resected on the forty-fifth day of the disease and several ounces of putrid pus were removed. A rubber drainage tube was inserted. The temperature came down somewhat, but the patient's condition remained poor. Five days later a chest x-ray revealed a drained pleura and a retracted lung (Fig. 2). Seventeen days after operation, the edges of the wound gradually became swollen and inflamed and within two or three days the margins became necrotic. Necrosis continued to spread in spite of frequent cutting away of the dead tissue, and during the next two weeks a steadily progressive gangrenous ulcer developed around the drainage site. One month after operation and sixteen days after the infection of the chest wall, one of us (F. L. M.) was asked to see the patient. The appearance then was that shown in Fig. 3, which is typical of progressive bacterial synergistic gangrene.

The man was desperately ill and his death was expected from day to day. Any operative procedure would almost certainly have precipitated his death, even the simple excision of the ulcer. He was, therefore, placed on penicillin therapy with a dosage of 200,000 units a day, being given 25,000 units intramuscularly every three hours. Twice a day, 10,000 units were also instilled through a tube into the pleural cavity. A culture of the necrotic margin yielded a mixture of organisms including the microaerophilic, nonhemolytic streptococcus and a hemolytic *Staphylococcus aureus*, the combination of organisms which has been demonstrated in other cases to be the etiologic factor in progressive bacterial synergistic gangrene. There were also present an anerobic hemolytic streptococcus, and an aerobic nonhemolytic streptococcus, a *Clostridium welchii*, a member of the pseudomonas group, and *Bacillus subtilis*.



Fig. 1 (Case 1). Lung abscess fifteen days after the onset of symptoms.

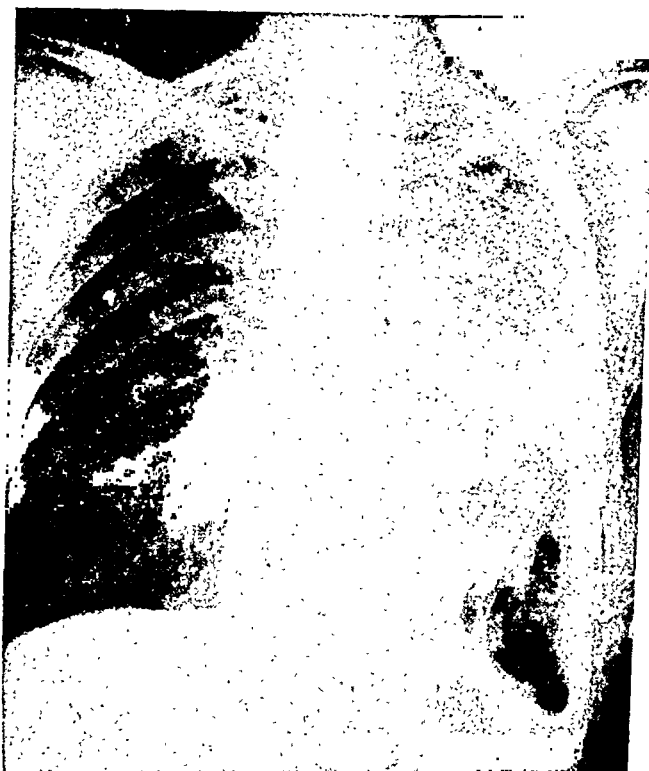


Fig. 2 (Case 1).—After drainage of putrid empyema, the lung with the abscess cavity has retracted upward; this is the fiftieth day of the disease.

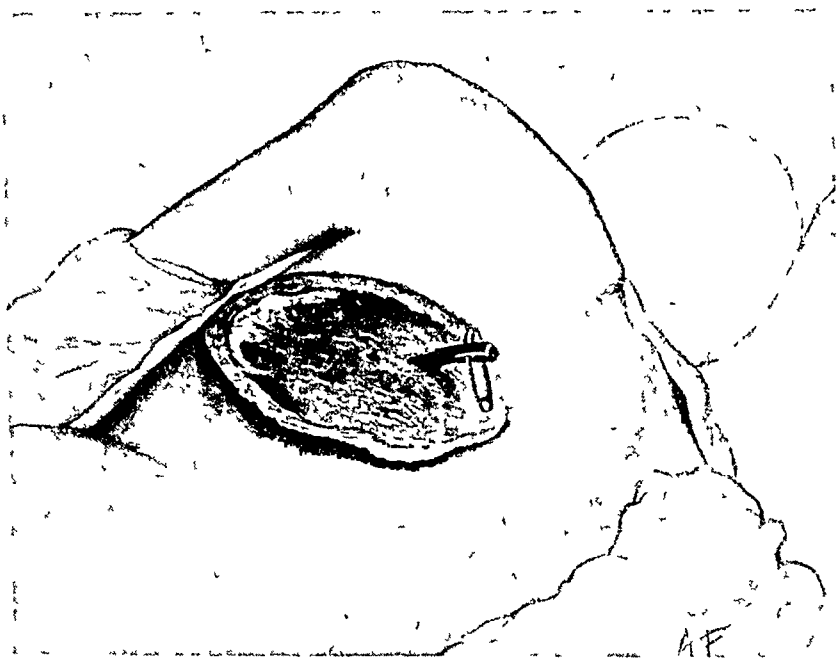


Fig. 3 (Case 1).—The lesion sixteen days after the development of the ulcer. This shows the drainage wound surrounded by a wide area of bright red granulations, a narrow zone of gangrene interrupted in two or three places around the circumference, firmly adherent to the raised necrotic zone and at the periphery, a zone of erythema varying in width from a few millimeters to about three centimeters



Fig. 4 (Case 1).—This is the one hundredth and sixth day of the disease; the infection has spread to the right lung and the fluid level is seen on the left side.



Fig. 5 (Case 1).—This is the one hundredth and twenty-fifth day of the disease; the lungs are clearing.



Fig. 6 (Case 1).—One year after the onset of the disease; the lungs show only a residual fibrosis.

Within one week, there was marked improvement and the progress of the ulcer was halted. The necrotic tissue gradually separated off. After ten days, the wound was clean and granulating with very little discharge from the pleural cavity. Furthermore, the process in the lung cleared, although multiple cavities were still evident within the left lower lobe. From that time on, his condition gradually improved. The cough and expectoration diminished and his appetite and strength increased. The pleural cavity closed. On the twenty-fifth day, the penicillin was reduced to 50,000 units daily. However, a few days later, x-rays revealed a fluid level in the upper left pleural cavity and a spread of infection to the lower right lobe (Fig. 4). The dose of penicillin was, therefore, raised to 100,000 units a day. The lung fields then gradually cleared and the patient was allowed up. Epithelium grew in rapidly from the margin of the ulcer. Pinch grafts were then applied to the ulcer and the defect was rapidly covered with epithelium. The lung lesions progressively and rapidly diminished and he left the hospital just two months after the beginning of the penicillin therapy (Fig. 5). He has remained well during the succeeding eight months (see Figs. 6 and 7).



Fig. 7 (Case 1).—This shows the healed scar six months after wound healing.

This case illustrates the failure of sulfadiazine to prevent the development of a putrid lung abscess which later developed an associated progressive bacterial synergistic gangrene of the chest wall following the drainage of a putrid empyema. Although there were multiple lung abscesses, which were not drained surgically, the whole process came under control with penicillin. As far as we know, this is the first case of this kind on record in which the patient was treated successfully with penicillin.

CASE 2 (Presbyterian Hospital No. 744592).—G. H., aged 53 years, was admitted May 2, 1944, and discharged July 14, 1944 (under the care of H. D. H.).

History.—Suddenly after breakfast one morning, without previous symptoms, the patient began to have pains in the midabdomen coming on in waves and growing gradually more and more severe. The pain was relieved somewhat by flexing the thighs. After a few hours, the pain gradually shifted to the lower abdomen with local tenderness in that region and pain across the lower back. There was no nausea, vomiting, or fever.

Physical Examination.—A mass was felt in the lower right side of the abdomen, which was quite tender, hard, and lobulated. The muscles of the abdominal wall over it were spastic. Elsewhere, the abdomen was quite soft and nontender.

Course.—An emergency operation was performed about nine hours after the onset of symptoms. The findings were quite unusual. There was an opening in the mesentery of the

terminal ileum about 50 cm. from the ileocecal valve. Through this opening, a loop of small intestine had herniated itself, running from left to right. The loop was about 25 cm. in length, swollen and obviously gangrenous. The entire terminal ileum had rotated on its mesentery including the herniated loop so that the intestine was gangrenous from a point about 2 cm. above the ileocecal valve upward for a distance of over 100 cm. The vessels in this portion of the mesentery were thrombosed. The gangrenous intestine was excised and an ileocecostomy was done. An enterostomy tube was then placed in the small intestine just proximal to the anastomosis, with a Witzel technique. The enterostomy tube was brought out at the lower end of the wound, which was then closed around it by means of interrupted sutures of No. 00 chromic catgut with a bolt suture of heavy silk taken from the skin on the right of the wound to the linea alba on the left as a tension suture. A culture from the peritoneal cavity preliminary to the resection showed no growth of organisms.

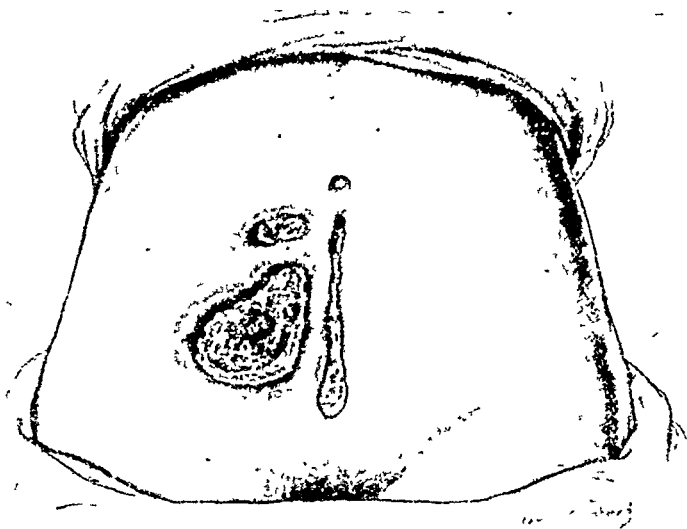


Fig. 8 (Case 2).—An artist's drawing of the lesion showing the central area of granulation tissue, a zone of suede leather gangrene around part of the margin, the raised purple zone, and the wide erythema. The small lesion above coalesced with the large lesion before penicillin was begun.

The patient was given sodium sulfadiazine, at first intravenously, and then sulfadiazine by mouth. On the fourth day, the sulfadiazine level had reached 18 mg. per cent. At that time there was a negative fluid balance with very little renal outflow and the urine showed sulfadiazine crystals and a few red blood cells. The sulfadiazine was stopped. Everything seemed to progress satisfactorily except for a moderate rise in temperature to 101.2° F. on the seventh day. The ileostomy tube was taken out on the eleventh day and the sutures were removed. However, around the bolt suture hole, an infection appeared on the fourteenth day and this gradually spread, appearing first as a raised dusky area of skin which steadily increased in area. On the twenty-second day, penicillin was introduced into the center of this area but it had very little effect. Gradually an ulcer formed and the whole region became extremely tender and painful. Her temperature gradually mounted, rising with moderate spikes from 101 to 102° F. and on the thirty-fifth day it was recognized as a typical progressive bacterial synergistic gangrenous ulcer with an inner zone of gangrene, a middle raised purple zone, and an outer erythematous zone. The whole lesion was approximately 8 by 10 cm. in diameter (Fig. 8). On the thirty-seventh day, penicillin was started intravenously in a dosage of 25,000 units every three hours. It was given continuously as an intravenous drip, 200,000 units being introduced in twenty-four hours. This treatment was followed by a striking improvement in the whole process. The spread of the infection ceased, the necrotic margin separated off spontaneously, and the whole area flattened down to the level of normal skin. The granulations took on a healthy appearance and new skin began to grow in from the margin. Penicillin was stopped on the forty-eighth day, after nine days of treatment.

Cultures from the lesion before the administration of penicillin revealed the essential organisms, a microaerophilic nonhemolytic streptococcus and a coagulase positive hemolytic *Staph. aureus*. There was also present a microaerophilic hemolytic streptococcus. On the

third day after stopping the penicillin, cultures of the wound showed no growth. On the twenty-seventh day after the start of penicillin, the patient consented to a skin graft. This might have been done fully two weeks earlier. Twenty small, deep, Davis skin grafts were planted from the thigh, all of which were successful and the wound was completely covered with epithelium ten days later (Fig. 9).



Fig. 9 (Case 2).—The healed scar nine months after wound healing.

CASE 3 (Presbyterian Hospital No. 763838.—B. B., aged 42 years, was admitted Nov. 9, 1944, and died Dec. 27, 1944 (under the care of F. L. M.).

History.—One and one-half years before admission, a boil developed on the lateral side of the right leg. It broke down and then formed an ulcer which gradually spread with a gangrenous margin, leaving in the center a granulating area on which epithelial islands appeared. Soon similar lesions developed on other parts of the body. They failed to respond to any treatment tried and the patient was finally admitted to a suburban hospital. Here he was given 550,000 units of penicillin over a period of three weeks. Penicillin was also applied locally but without benefit. Sulfadiazine and gentian violet were also tried without effect. He was then sent to New York to the Presbyterian Hospital on the dermatology service. At that time, there were five large and four small gangrenous ulcers on the body. Here a search was made for amebae but none were found either in the ulcers or in the stools. The Wassermann and Kline tests were negative. Wet dressings of potassium permanganate were applied without effect. The patient was then referred to the surgical service.

Physical Examination.—The patient was a well-developed, well-nourished man lying quietly in bed without much discomfort, but appearing chronically ill. There were twelve gangrenous ulcers on different parts of his body in varying stages of development. There was one on the right leg, one on the left thigh, one over the right hip, six on the anterior part of the chest, and three on the inner surface of the right arm, which had developed since admission to the hospital. These lesions, while they had most of the characteristics of the progressive bacterial synergistic gangrene as described in previous reports, differed in three respects. In the first place, they were multiple; second, they were not excruciatingly painful; and third, the zone of gangrene was relatively narrow (see Figs. 10 to 13).

They were all characterized by a raised, purple margin, irregular in outline and surrounded by a zone of erythema varying from $\frac{1}{2}$ to 2 cm. Inside the raised purple zone, there was a gangrenous zone of varying width. In many places it was entirely absent and in other places it was as much as 1 cm. wide. The infection was apparently active in all of

the ulcers. There was a good deal of necrosis of the subcutaneous tissue with innumerable, small pockets in the subcutaneous fat and innumerable islands of granulation tissue, some of which looked healthy, while others appeared infected. In the central portion of the ulcers, there was a varying amount of epithelium which had evidently arisen from residual islands not destroyed by the infection. This was most marked in the oldest lesion which was on one leg, while there was only a small area of new epithelium on the lesion over the hip and the most recent lesions on the arm.

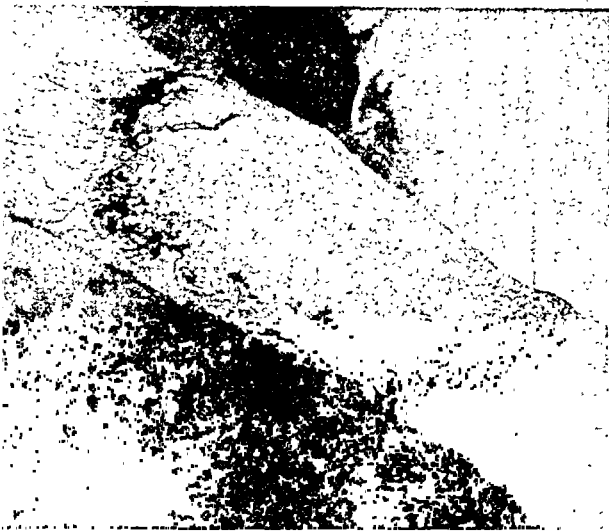


Fig. 10.



Fig. 11.

Fig. 10 (Case 3).—Lesion on the leg where the disease started one and one-half years before, showing a wide central area covered with thin regenerated epithelium, a spreading margin with only a narrow shread of gangrenous skin around part of the margin, a raised purple zone, and a narrow zone of erythema.

Fig. 11 (Case 3).—Two large, old areas on the chest showing narrow gangrenous zones and considerable areas of regenerated epithelium which have become secondarily broken down by the infection. The two smaller areas below the clavicles show more typical suede leather gangrene, raised purple zone, and wide erythema. Two small areas in the early stages are seen on the lower right side and two more on the inner side of the arm.

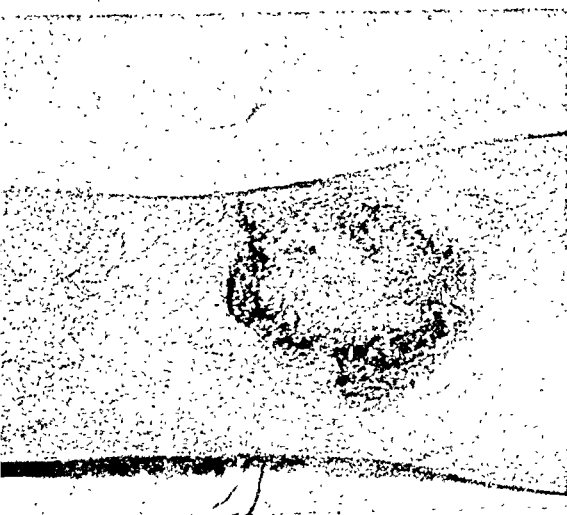


Fig. 12.



Fig. 13.

Fig. 12 (Case 3).—One of the older lesions above the left knee with narrow gangrenous and raised purple zones and a considerable area of regenerated epithelium.

Fig. 13 (Case 3).—One of the more recent lesions on the right hip and flank showing a wider zone of suede leather gangrene, a raised purple zone of varying width, and a very small area of regenerating epithelium.

Cultures from these ulcers showed a multitudinous number of bacterial species including the microaerophilic nonhemolytic streptococcus and the *Staph. aureus*, the essential organisms in the production of this disease. There were also *E. coli* and *Pseudomonas pyocyanea*, aerobic nonhemolytic streptococci, diphtheroids, and microaerophilic hemolytic streptococcus.

Course.—Patients in two previous similar cases having responded well to large doses of penicillin without surgery, the patient was given 25,000 units every three hours intramuscularly, but there was very little improvement after a course of two million units in ten days. The ulcers became cleaner, but the margins advanced, particularly the most recent lesions. It was decided, therefore, to excise the ulcers. When that decision was made, the penicillin was stopped and during the next four days the exudate from the ulcers considerably increased. Penicillin was, therefore, tried again for ten days but again the improvement was not sufficient to warrant continuing it. All but one of the lesions were, therefore, excised and three different kinds of local treatment were tried—penicillin, streptothricin, and zinc peroxide, each in a carbowax base. One ulcer was left as a control. All three of these forms of treatment seemed to have control over the infection but streptothricin produced the cleanest wound.

Suddenly early in the morning of the seventh postoperative day, the patient went into profound shock and died. Autopsy revealed a large pulmonary embolus, apparently coming from the iliac veins.

DISCUSSION

The first case illustrates a typical chest wall lesion resulting from the drainage of a putrid empyema arising from a lung abscess. The patient's condition was extremely critical and it seemed to those who were taking care of him that the outlook was hopeless. There can be no question about the efficacy of penicillin in this case, even though the bacteriologic examination showed a mixture of organisms. The extensive lung involvement must have been the chief factor in his downward course before the administration of penicillin and this became reactive when the dose of penicillin was reduced, coming under control again when the dose was increased. This seems to be added evidence that penicillin was effective in controlling the lung condition as well as the ulcer. At one time, we thought surgery would be necessary, but steady improvement both in the clinical course and in the x-ray findings obviated the necessity for surgery in the lung as well as in the chest wall.

The second case illustrates the abdominal wall form of this disease, the organisms almost certainly coming from the intestinal tract and establishing themselves in the abdominal wall where the circulation was compromised by the pressure or tension of the bolt suture. In the great majority of cases, this element of pressure by a suture can be demonstrated and indicates not only the necessity for a synergistic action by bacteria, but a third factor which lowers the resistance of the tissues, permitting the establishment of an organism not primarily pathogenic. In this case, the suture was carried deeply into the muscles of the abdominal wall and infection arose in the incision as well as around the suture. Furthermore, another organism, namely the hemolytic microaerophilic streptococcus, was also present and certain features of undermining seemed to indicate that we had here a combination of the synergistic gangrene and the undermining ulcer. However, the undermining, burrowing ulcers, in our experience, have not responded to penicillin and it does not seem likely that this was a major factor in the infection because of the prompt response of the lesion in this case to penicillin. Again surgical excision, which has been essential in the cure of this condition in the past, was obviated. Furthermore, the promptness of the response to penicillin leaves no doubt about the efficacy of the drug in this case. The patient tolerated the intravenous administration of penicillin and greatly preferred it to the periodic intramuscular injections which were extremely painful.

The third case falls into the group not associated with either the intestinal tract or the lungs, but the group in which the organism probably gets in as a secondary contaminant into an area compromised by the previous activity of the staphylococcus. Once established, however, the microaerophilic nonhemolytic streptococcus is the one which leads the advance into the periphery and prepares the ground for the secondary spread of the staphylococcus. It is the latter organism which is chiefly responsible for the death of tissue in the gangrenous zone and in the raised purple necrobiotic zone. The infection was obviously very superficial, as indicated by the extensive regeneration of the epithelium in the center of the older lesions. Penicillin, in this case, cut down the amount of exudate and probably had some antibacterial action on certain of the bacterial species, but the presence of Gram-negative rods in all of the lesions prevented its control of the infection. We demonstrated in the laboratory that the *E. coli* and *Ps. pyocyanea* both elaborated penicillinase, which completely inactivated penicillin in vitro. It may very well be that if we could have controlled these Gram-negative rods by some other medication, infection even though very extensive might have come under control with the penicillin. There can be no doubt about the improvement during the period of penicillin administration, but it was felt that the wide extent of the process would require surgical removal of a great part of the diseased tissue. The patient stood the operation very well indeed, and the postoperative course was entirely satisfactory up to the time of the pulmonary embolus, which was a most unfortunate accident and thoroughly unexpected. We do not feel that failure in this case in any way detracts from the value of penicillin in the disease, but emphasizes the necessity for a complete bacteriologic analysis of such lesions and the control of all of the bacteriologic elements. The inactivating of penicillin by secondary contaminants certainly must be recognized as one of the important limitations to penicillin therapy.

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ILEOSTOMY AND COLECTOMY IN CHRONIC ULCERATIVE COLITIS

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REVIEW of the statistics on cases of nonspecific ulcerative colitis at the University of Minnesota Hospitals for the ten years ending Jan. 1, 1944, showed an 8 per cent mortality among those twenty-five patients treated surgically and a 28 per cent mortality among those fifty-seven confined to conservative types of management.¹ Since these findings indicate the importance of surgical care in these cases, it seemed worth while to try to make a thorough study of the most satisfactory surgical techniques and methods of postoperative care. This present emphasis on the surgical management is, of course, a temporary one to be employed only until the true nature of the disease shall have been discovered, when it is presumed that less radical measures may suffice.

The previous study pointed out that the safest procedure in those cases requiring any surgery at all is to perform ileostomy and to allow at least three months to pass before undertaking other procedures. The indications for ileostomy have been presented elsewhere, and will be only mentioned here. Nonspecific ulcerative colitis can be classified into the fulminating cases, the moderately severe ones with remissions and exacerbations, and the very mild ones. These last cases, the very mild ones, can usually be handled medically. All others are candidates for ileostomy at the University of Minnesota Hospitals. Emergency indications are: uncontrollable hemorrhage, fulminating disease, impending perforation, and obstruction. Elective indications are: chronic ulcerative colitis resisting all forms of medical treatment, segmental ulcerative colitis, very early ulcerative colitis, and polyposis including those cases with possible malignancy.

¹This paper was to have been presented at the meeting of the Society of University Surgeons, New York, N. Y., Feb. 8, 1945. (Meeting canceled.)

The type of ileostomy now employed has developed gradually in the past few years. At first, all ileostomies were of the double-barreled type, the loop being brought out through the main incision. Most of these wounds healed nicely, but about one-third of them broke down under the influence of the unspent digestive ferments poured forth from the ileostomy. This has, in the past, been one of the great objections to ileostomy posed by internists and surgeons alike. Excoriation of the skin, which results from constant bathing in the unspent secretions coming from the bowel, has been a second factor. Finally, the progressive emaciation born of loss of appetite and seepage of plasma from painful raw surfaces has caused many clinicians to throw up their hands in horror at the suggestion of ileostomy in any but the most extreme cases.

These problems seem to have been largely overcome by the employment of the ultimate regimen indicated in the present report. It has become the impression of most members of the surgical and medical staffs at the University of Minnesota Hospitals that ileostomy is less a burden than any but the most mild cases of colitis. One patient with ileostomy-colectomy does well enough to play professional football and to have declined to have ileoproctostomy performed.

In the sixteen months after Jan. 1, 1944, twenty-three new cases of ulcerative colitis have come to the attention of the medical and surgical staffs at this hospital. One was localized and was resected by another member of the staff. Of the remaining twenty-two patients, only seven did not have surgery; thirteen had ileostomies as described. The remaining two had ileostomies by other methods by other operators; both developed fecal fistulas. Of the seven not receiving operation, two died, two improved, and three failed to improve.

This review of recent experience indicates the favor in which proper surgical management is held at the present time at this clinic. It has been learned by painful experience that the most extreme care and precision must be exercised with every detail of the preoperative, operative, and postoperative care of these cases, and with this finding in mind, the procedures employed are described.

ILEOSTOMY

Preoperative Preparation.—The bulk of the candidates for ileostomy have been troubled with profuse liquid stools many times a day, the frequency and debility of which have been only increased by administration of the high-protein, high-calorie diets ordinarily employed at Minnesota on poor-risk patients.² It has, therefore, been the practice to fortify these individuals for ileostomy by continuous intravenous infusion of from 2 to 3 liters of 20 per cent dextrose solution in distilled water during the twenty-four to thirty-six hours before surgery. This is usually supplemented with plasma, as the plasma protein is ordinarily depleted. Crude liver extract (Campalon^{*}) and the available purified vitamins are added to the dextrose solution.

Preoperative preparation includes 100 mg. of pentobarbital the night before surgery, repeated in the morning if the patient is not drowsy, also morphine and hyoscine as in routine preparation for other procedures. Wangensteen nasal suction is instituted before the patient leaves the ward, and is maintained usually the next two days. Enemas are scrupulously avoided.

Operation.—

Anesthesia: The patient is made as comfortable as possible on the operating table, and an 8 cm. left lower rectus incision is made under ½ per cent metycaine local infiltration (Fig. 1). The rectus sheaths are not infiltrated with 1 per

^{*}Winthrop Chemical Company, New York, N. Y.

cent solution until exposed, as a precaution against puncturing the bowel. The rectus muscle is retracted laterally, and the abdomen entered.

Choice of level: No manipulation of the colon is performed. The desired segment of bowel can almost regularly be easily identified by the presence on the antimesenteric border of the terminal 10 cm. of ileum of the ileocecal fold described by Kelly and Hurdon³ (not mentioned in the standard anatomy atlases and texts). It is delivered into the field; the diameter of the bowel is measured and it is carefully inspected with a view to making the ileostomy definitely above the level of involvement.⁴ The mesentery is infiltrated with metycaine as far posteriorly as possible, and is divided at the chosen point for from 8 to 10 cm. toward the root, tying the well-isolated vessels encountered with No. 0 chromic catgut (Fig. 2).

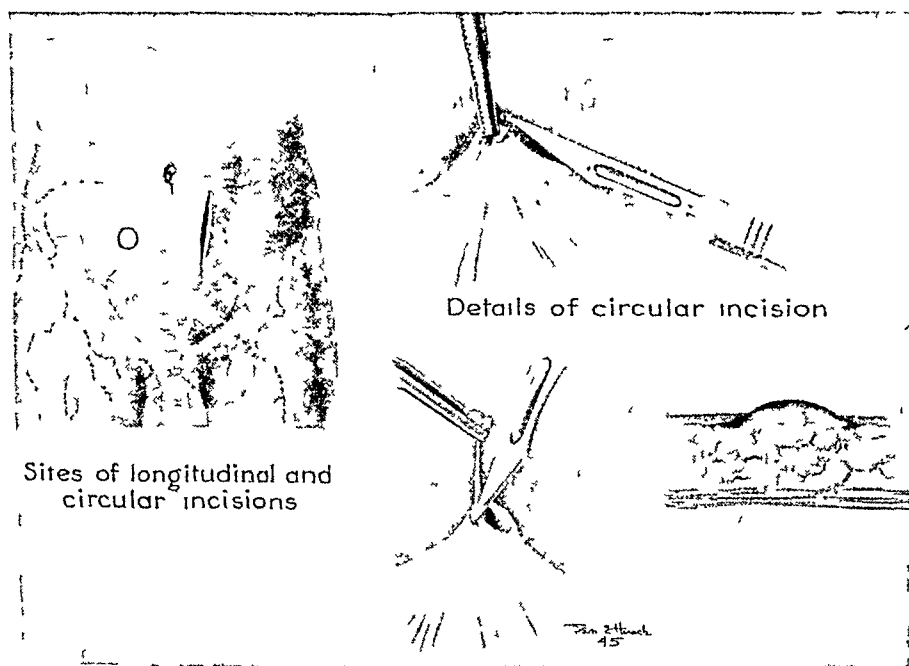


Fig. 1.—Details of the incisions employed for single-barreled terminal ileostomy. An 8 cm. left lower rectus incision is made. A circular skin incision two-thirds the diameter of the ileum to pass through it is made 6 cm. below the umbilicus and from 2 to 3 cm. to the right of the midline. The cuticular surface of the skin projects farther toward the center of the circular defect than the deeper layers; local anesthesia.

Division of ileum: After careful evaluation of the circulation of the bowel following this division of the mesentery, a segment is removed between clamps and both remaining ends are closed with Parker-Kerr catgut sutures, each suture being reinforced by three or four Halsted mattress sutures of No. 4-0 Deknatel silk. The distal stump is sutured to the mesentery (Fig. 2) to prevent intussusception, the ties are left long on the upper end to ease re-identification, and both are dropped back into the abdomen.

The resected segment is opened at once by the pathologist and examined for evidences of disease at this level. Presence of diseased bowel at the site of ileostomy favors fecal fistula formation and postoperative diarrhea, and dictates ileac resection upward until good bowel is reached.

Preparation of Circular Ileostomy Incision.—The optimal site for ileostomy on the abdominal wall is dictated in a large measure by the characteristics of the Koenig-Rutzen ileostomy bag. It should be from 6 to 7 cm. below the belt

*The terminal ileum has been involved in one-third of our reported cases.

line, and well away from the anterior superior spine of the ilium and the inguinal fold. In practice the usual position is 6 cm. below the umbilicus and 3 cm. to the right, the same site chosen by Cattell.⁴ The skin is infiltrated at this point, picked up, and buttonholed with a scalpel (Fig. 1). A circular defect, two-thirds the original diameter of the ileum to be passed through it, is made in such fashion that the cuticular layer projects farther toward the center of the circle than the deeper layers of the dermis, and may thus later be spread upward along the ileum somewhat (Fig. 1).

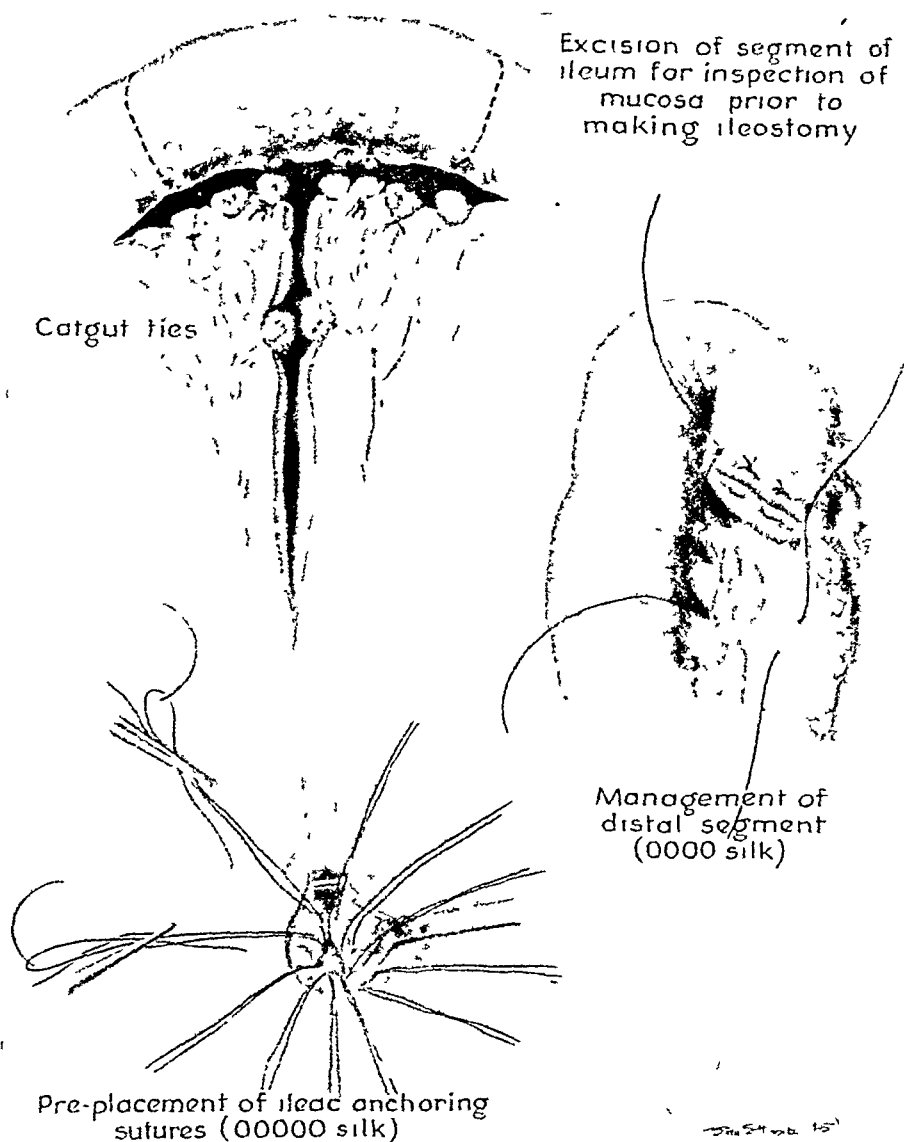


Fig. 2.—Single-barreled ileostomy. At the site chosen for ileostomy the mesentery is divided 8 to 10 cm. toward the root, using catgut ties. A segment of intestine is removed for immediate gross pathologic examination to rule out ulcerative ileitis at this level. Both remaining ends are closed by Parker-Kerr catgut and Halsted mattress No 4-0 silk sutures. The distal end is sewed to the mesentery to prevent intussusception. Lower figure shows placement of fine (No. 5-0) silk anchoring sutures in the rectus sheaths and peritoneum.

The rectus sheath is bluntly exposed and longitudinally incised just sufficiently to permit passage through it of a finger of the surgeon equal in diameter to the ileum as first exposed.

Ileac-anchoring sutures: Fixation of the ileum to the abdominal wall by fine (No. 5-0 Dektatel) sutures is best accomplished by preplacement of these

sutures, usually from ten to twelve in number, in the rectus sheaths and peritoneum before passage of the bowel through the defect (Fig. 2). Completion of these sutures is accomplished after delivery of the closed ileum by small submucosal bites in the bowel and serosal bites in the mesentery; the bowel is then slipped back into position for tying of the sutures (Fig. 3).

Mesenteric-anchoring sutures: Prior to passage of the ileum through the ileostomy defect, two or three sutures are placed on the mesenteric border and left temporarily without tying (Fig. 3). After securing the ileac-anchoring sutures already described, these mesenteric-anchoring sutures are employed to fix the mesenteric border to the peritoneum and posterior rectus sheath for from 4 to 5 cm. caudad to the ileostomy opening through the abdominal wall in an effort to minimize both prolapse and torsion of bowel about the loop coming to the ileostomy (Fig. 4).

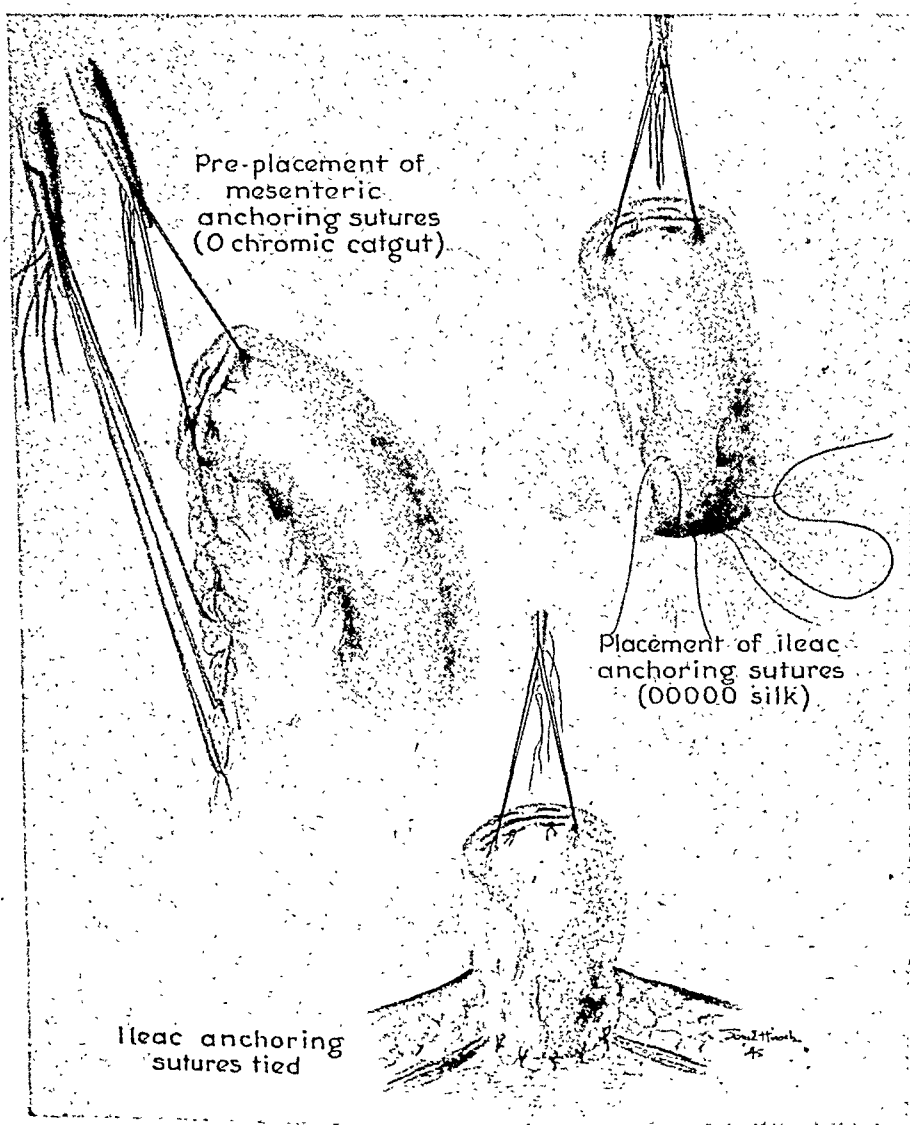


Fig. 3.—Single-barreled ileostomy. Sutures for anchoring the mesenteric cut edge to the anterior abdominal wall are placed before the closed orad stump of ileum is brought through the circular incision, to avoid inaccessible hemorrhage. After passage of the bowel through this incision, the sutures already anchored to the rectus sheath and peritoneum are all completely placed by submucosal bites (avoiding mucosa) in the ileum and subserosal bites in the mesentery. The bowel is then slipped back into place, and all sutures are tied and cut.

The ileum should now project about 3 cm. beyond the skin surface, and there should be good color to the bowel and an obvious pulsation of the arteries of the mesentery outside the skin, measures which have been found to militate against later stenosis of the stoma.

Skin sutures: Fixation of the skin edge to the bowel is essential to the subsequent comfort of the patient, as will be indicated. It is best accomplished with No. 000 chromic catgut sutures catching just the cuticular margin. The bowel is worked down into the subcutaneous tissue and the skin edge elevated in the

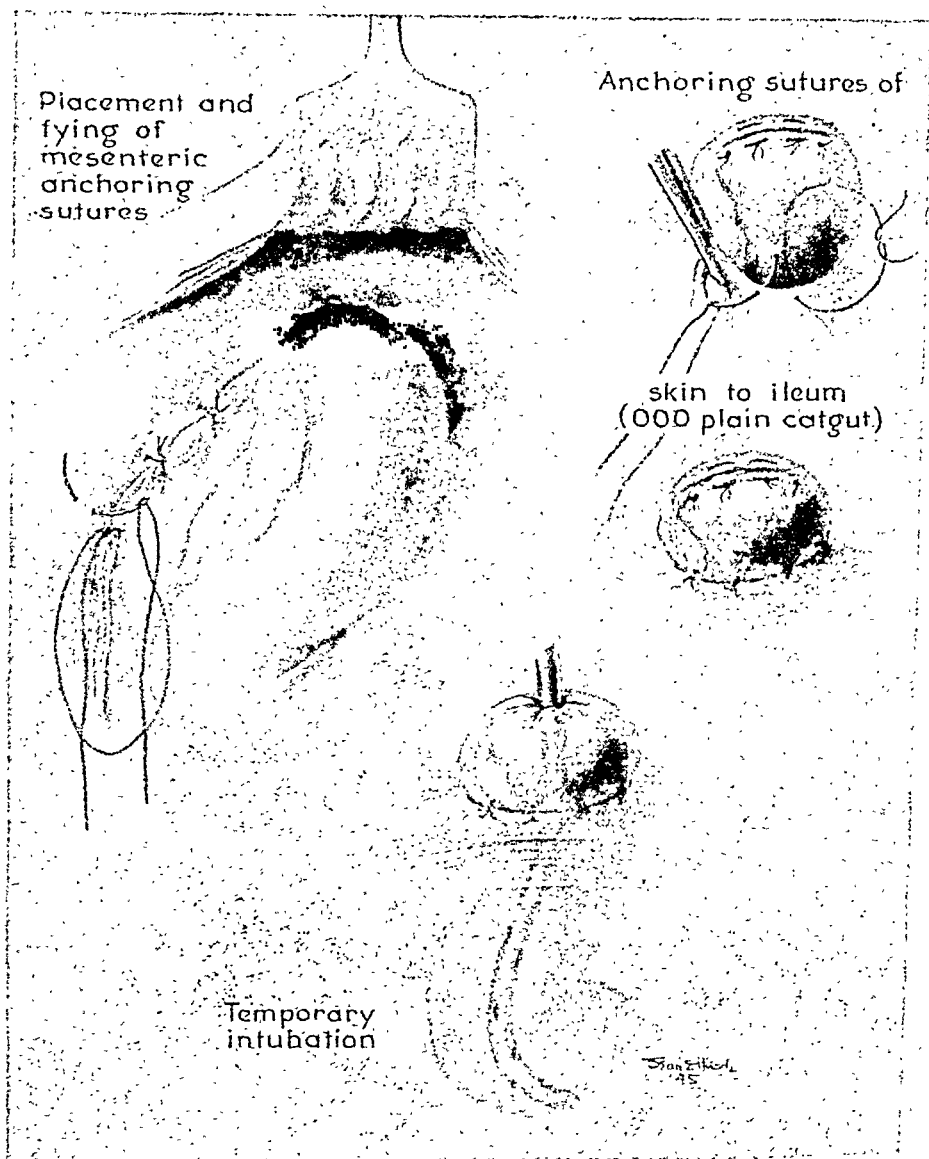


Fig. 4.—Single-barreled ileostomy. The mesenteric-anchoring sutures are completed and tied. The skin is sutured to the ileum at a point 1.5 cm. distal on the bowel to the point where it lies naturally. The serocutaneous junction is covered with petrolatum gauze and the ileum intubated.

process, so that the attachment ultimately lies $1\frac{1}{2}$ cm. out from the point where the skin at first lies naturally against the ileum (Fig. 4). This is best done at once after tying the deep anchoring sutures, before the edema from manipulation is marked. Usually $\frac{1}{2}$ Gm. of sulfanilamide powder is implanted between the bowel and the subcutaneous fat.

The left rectus incision is closed with interrupted silk, No. 000 and 0000 Deknatel, and a dry gauze dressing is applied. Petrolatum gauze is placed around the ileostomy and a No. 14 French, soft rubber catheter with from ten to twelve holes is inserted from 6 to 7 cm. and secured with a catgut purse-string suture (Fig. 4).

Postoperative Care.—

Intubation: The patient returns to the ward awake and comfortable. Full Wangenstein suction is applied to the nasal gastric tube and about one-half suction to the ileostomy catheter. After the first twenty-four hours, appreciable amounts of fluid are usually removed through the catheter. Usually the nasal tube can be removed in forty-eight hours without subsequent discomfort. The ileac catheter must be removed in four days to avoid leakage, and at this time healing is adequate to discontinue aseptic management of both incisions.

Skin care: In removal of the catheter, the following procedure has proved most satisfactory. All dressings are removed, and the skin for from 12 to 14 cm. around the bowel, including the rectus incision, is covered with a $\frac{1}{2}$ cm. layer of the paste described by Ladd and Gross⁵ (as used here: aristol 100, castor oil 600, zinc oxide 320, petrolatum 1,280). By the actual cautery the catheter is loosened and the end of the bowel widely opened, care being taken to remove completely the valvelike inverted lips of ileac wall. Drainage is thereafter rather profuse and liquid. The patient now assumes much of the care of the ileostomy, and keeps the skin carefully protected from the ileac secretions by free application of paste and hourly changes of dressings. Nursing help is needed chiefly during the night for the next three days.

About seven days after surgery the patient is fitted with one of a supply of Koenig-Rutzen^{6, 7} bags kept on hand for the purpose, and may be up and about the ward (Fig. 5). As soon as the patient masters the management of the bag, usually in another two to three days, he goes home.

Twenty-five days after surgery, shrinkage of the exposed ileum is complete. At this time the patient returns for measurement of the exact outline and position of the mucocutaneous junction, data required for preparation of the patient's Koenig-Rutzen bags.*

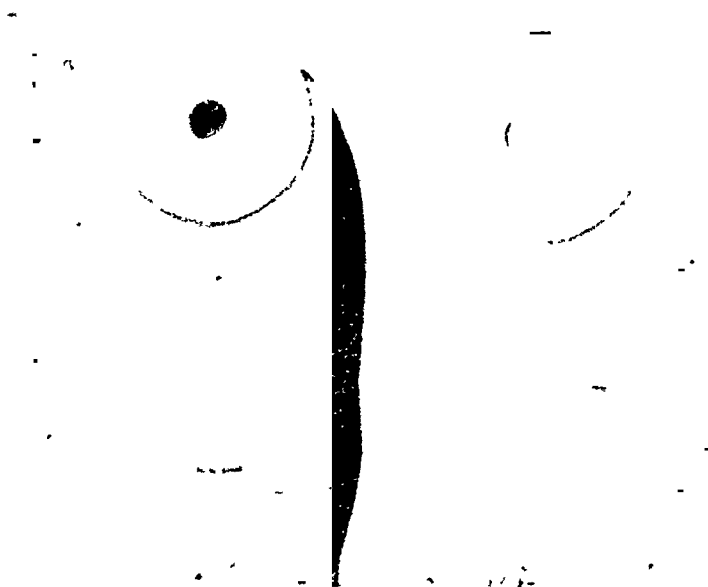
Double-barreled ileostomy: In certain instances stricture or actual obstruction of the colon may be present, or the patient may be too desperately ill to withstand such a procedure as that outlined, even under local anesthesia. In these patients it is safer to perform a double-barreled ileostomy, making the initial 5 to 6 cm. incision under local anesthesia at the site chosen for ileostomy, and filling this incision with the loop of bowel instead of attempting any skin-to-skin approximation at all. A glass rod is passed through the mesentery to support the ileum, but the No. 5-0 silk peritoneal anchoring sutures and catgut skin sutures are used nevertheless (Fig. 6). Spillage into the distal loop can be prevented for about six weeks by a tie of umbilical cord tape around the distal ileum just outside the skin.

Postoperative care is essentially the same as in the single-barreled ileostomies. The bowel is cut down to the glass rod one week after operation before the application of a bag.

*Obtained from H. W. Rutzen, 1819 Irving Park Road, Chicago, 13, Ill. The patient is supplied with two bags, one for day and one for night use. The bag is made of soft rubber and has a flat brass, rubber-covered facing made to order to fit the patient to hold it against the skin around the stoma. Bland rubber cement is used to fix this facing to the skin for 3 cm. around the mucocutaneous junction. Bags are removed for change each morning and night by application of petroleum naphtha with an eyedropper. They may be emptied between changes through a vent in the lower corner of the bag, otherwise secured by a rubber band.

Rationale of Procedures.—

Anesthesia: Early in the surgical management of the disease in this clinic, the anesthetic of choice was ethylene supplemented with ether. Under this anesthesia one of these debilitated patients died before the skin incision was completed. Another died upon exposure of the peritoneum. More recently we



A.



B.

Fig. 5 A and B.—The Koenig-Rutzen bag is a rubber-covered brass facing with an opening made individually to fit the bowel, and a bag to hold discharges. It is cemented to the skin, and may be emptied from the lower end when necessary.

have had one apparently good-risk patient go into shock during ileostomy under spinal anesthesia. Another patient went into deep shock following administration of a low spinal anesthetic by a physician-anesthetist, requiring over two liters of plasma and blood to restore the pulse and blood pressure without sur-

gery at all. Two days later, after intravenous infusion of 20 per cent glucose solution, he underwent ileostomy uneventfully under local anesthesia.

Following the adoption of McKittrick's suggestion that ileostomy be done under local anesthesia, no patients have developed shock during this operation. This includes about two dozen cases.

The circular incision: The policy among most surgeons is to perform ileostomy by exteriorization of a loop or end of the bowel through the incision, with closure of the abdominal wall around the ileum. This was the policy at the University of Minnesota Hospitals also, until one unfortunate case of marked wound breakdown led to a review of the cases. The policy since has been to avoid skin-to-skin approximation in the neighborhood of the stoma. Since the adoption of this policy, primary union of both the main and the ileostomy incisions has occurred in every case (Table I).

Double-barreled ileostomy is more commonly used elsewhere than single-barreled ileostomy, but the latter has been preferred here because of greater ease of later colectomy, absolute prevention of passage of ileac contents into the colon, and lower frequency of hernia formation beside the bowel.

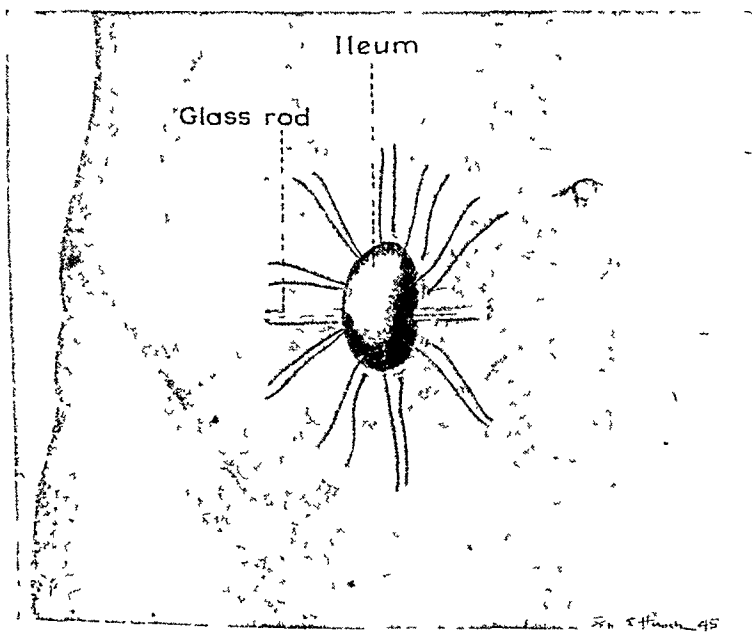


Fig. 6.—Double-barreled ileostomy is reserved for patients with obstruction or too severe a disease to stand the longer procedure. It is performed through a 5 cm. incision which is completely filled by the bowel. Peritoneal and skin sutures are placed as in the single-barreled ileostomy.

Skin care: Skin care according to the measures described has led to virtual freedom from erosions throughout in all but two of the cases in the group of twenty under discussion. In these two there has been temporary erosion, in one case as much as 2 cm. in radius around the stoma, but the erosions have healed well under the regimen outlined.

Several other appliances have been employed. Dressings changed frequently resulted usually in terrific skin excoriation. The Perry cup was demonstrated to us on one patient and fitted on another. It was considered uncomfortable by our patient, and it is less secure than the Koenig-Rutzen bag. The Traveler bag has not been tested here.

Replacement of distal stump inside the abdomen: Lahey⁹ and Garlock¹⁰ recommended bringing both ends of the divided ileum out through the skin.

TABLE I. WOUND HEALING IN ILEOSTOMIES FOR CHRONIC ULCERATIVE COLITIS
(JAN. 1, 1934, TO MAY 10, 1945)

	TOTAL	PRIMARY HEALING	DISRUPTION OF WOUND	FECAL FISTULA	LATE HERNIA OF PROLAPSE	LATE STENOSIS
Ileostomy made as described	20*	20	0	0	1†	0
Ileostomy made by other methods						
Ileostomy in a long incision	22	14	8‡	0	3	1
Ileostomy through stab wound but sutured from inside abdomen	3	2	1	2	1	0

*Sixteen single barreled; four double barreled. There were two deaths, both in the double-barreled group. One died of a well-organized pulmonary embolus nine days postoperatively. This patient had had strict medical management and absolute bed rest for one month before surgery. The pathologist felt the thrombus had formed before surgery. One comatose late case died five days after emergency ileostomy with purulent ileac drainage and shock. Autopsy showed chronic ulcerative colitis, ileitis, jejunitis, and gastritis.

†Procedure deviated from that described in that the rectus sheath opening was made large enough to admit two fingers.

‡Four wounds healed after one to twelve months. Three operations were redone after six months to three years. One patient died of massive wound breakdown and skin excoriations.

the upper through the incision and the lower through a stab wound elsewhere. This policy has apparently been dictated at the Lahey Clinic by blowout of the closed lower end when dropped into the abdomen. An added stoma to cover and dress seems to us at this clinic to add considerably not only to the difficulty of later colectomy but also to the psychiatric instability of these already insecure patients.

Secure closure methods have been described. Martzloff and Burget¹¹ found that properly closed loops of ileum, dropped back into the abdomen of dogs, perforated elsewhere than at the suture lines. It has been found in the experimental laboratory here that simple obstruction in the dog's ileum by division and proper closure culminates ordinarily in perforation of the bowel well apart from the suture line.¹²

With these facts in mind, we have had no fear of the procedure described, and have had no reason to regret dropping the closed end back into the abdomen.

Closure of oral stump in preparation of ileostomy: Closure of the ileac stump prior to bringing it through the abdominal wall was adopted because it decreased contamination, both from the cut end otherwise held in a clamp of some sort and from tearing of the ileum which was found frequently to occur, in trying to pass it through the necessarily narrow ileostomy opening in the abdominal wall. It also facilitates clean temporary catheter intubation at the end of the procedure.

Fixation sutures: Certain factors have proved particularly important in eliminating prolapse and herniation around ileostomies. The most important of these is the accurate suturing of the wall and mesentery of the ileum to the parietal peritoneum and rectus sheaths just as securely with fine silk sutures as if the bowel were being anastomosed.*

Mesenteric anchorage and prevention of prolapse: Garlock¹⁰ has recommended inclusion of the mesenteric cut edge in the peritoneal closure caudad to the single-barreled stoma as a means of reducing prolapse development. Cattell⁴ follows the same procedure. The procedure of suturing this edge to the anterior abdominal wall was adopted in line with this suggestion, and seems to have been partially effective. There has been one case of prolapse for almost

*This policy was adopted after careful dissection of a series of colostomies during the procedure of closure. Certain other observations were made at autopsy and clinically. With but one exception, no colostomy (or ileostomy) was found to be free from herniation beside the bowel unless a colostomy had been performed which included placement of sutures as described. Almost every case of stenosis of colostomies was found to be associated with such herniation and apparently secondary to it. Of those made as described, only one colostomy hernia has developed.

15 cm. in this group, however, and the only factor which seemed likely to play a rôle in this failure was that the rectus sheath incision had been made large enough to admit two fingers. Since adoption of a rectus sheath opening only large enough to admit one finger equal in diameter to the ileum *as first exposed*, no prolapse has occurred.

Size and type of suture material: Ileostomies were early done with heavy silk sutures. Many of these wounds drained for weeks or months beside the bowel, with discharge of sutures from time to time and great disability, long hospitalization, and psychic disturbance to already unstable patients. Catgut was, therefore, adopted for all sutures and ligatures except the ileac-anchoring sutures, where silk was known to be more reliable. Fine silk sutures of No. 5-0 Deknatel, 1 pound test at this point, are at least as strong as the ileum in which they are placed, and in no instance has use of this size stitch for ileac anchorage been followed by discharge of serum, pus, or suture material from the wound.

Placement of ileac-anchoring sutures: Two ileostomies recently performed by others at the clinic have been followed by development of fecal fistulas, one through the main incision and both through the skin close to the bowel. In one of these the segment employed was involved with extension of the disease from the colon. In both of them the ileac-anchoring sutures were of heavier grade and were placed from within the abdomen, making precise submucosal placement *without entering* the lumen virtually impossible.

In a third case of placement from within the abdomen, the lateral side could not be reached or visualized, and sutures were not placed there. Herniation developed.

The adequacy of the suture method just described is testified by the finding at autopsy of clean healing of the ileum to the abdominal wall in the case of involvement of the entire stomach, ileum, and colon, even though the mucosa was largely ulcerated away and the entire ileac wall heavily involved at the site of ileostomy.

Duration of ileostomy procedure: The rather meticulous procedure outlined cannot be done hurriedly. Under local anesthesia there is little premium on time except for the convenience of the surgeon. The average time including anesthesia in the twenty cases reported in this paper was two hours thirty minutes. Recollection of prolonged suffering from painful open wounds, extensive excoriations, and repeated operations, as well as of the weeks and months I have spent trying to salvage the situation for patients in whom the operative procedures have been done hurriedly and improperly, is adequate incentive to continue to spend this amount of time with them in the proper performance of the ileostomy in the first place.

Skin care: It is true, as much in the postoperative care as in the operative procedure, that a little time spent with the patient is an ounce of prevention.

Various methods of management after ileostomy are feasible. Tincture of benzoin, tannic acid, petrolatum, and vinylite resin¹³ have proved entirely inadequate to prevent excoriations. The use of rubber dam cemented to the skin with Koenig-Rutzen cement is satisfactory, but requires close watching and changes at least twice a day. The most useful preparation found so far at this clinic is the paste of Ladd and Gross,⁵ which coats the skin with a good protective layer.

It is at this stage that the failure of many ileostomies is caused. *Excoriation and breakdown of the skin are relatively easy to prevent but extremely difficult to heal in the constant bath of irritating ileac discharge.* Early excoriation

tion at this stage or later often may be aided by use of rubber dam precisely fitted around the bowel and cemented to the skin. This may be removed two to three times daily for one-half hour warm baths, with the water level well above the stoma. Dusting the area lightly with zinc stearate powder before application of the skin cement is also helpful. Very occasionally patients have been placed face down on a mattress with a hole in it so secretions fall away without touching the skin.

Once the patient has progressed to use of the Koenig-Rutzen bag, other measures are usually unnecessary. The management is quickly learned by the patient, who is the one person most interested in care of his skin, but in the experience of this clinic is not to be turned over to most internes or to nurses not specially tutored, for trouble and even disaster have almost invariably followed such delegation of care.

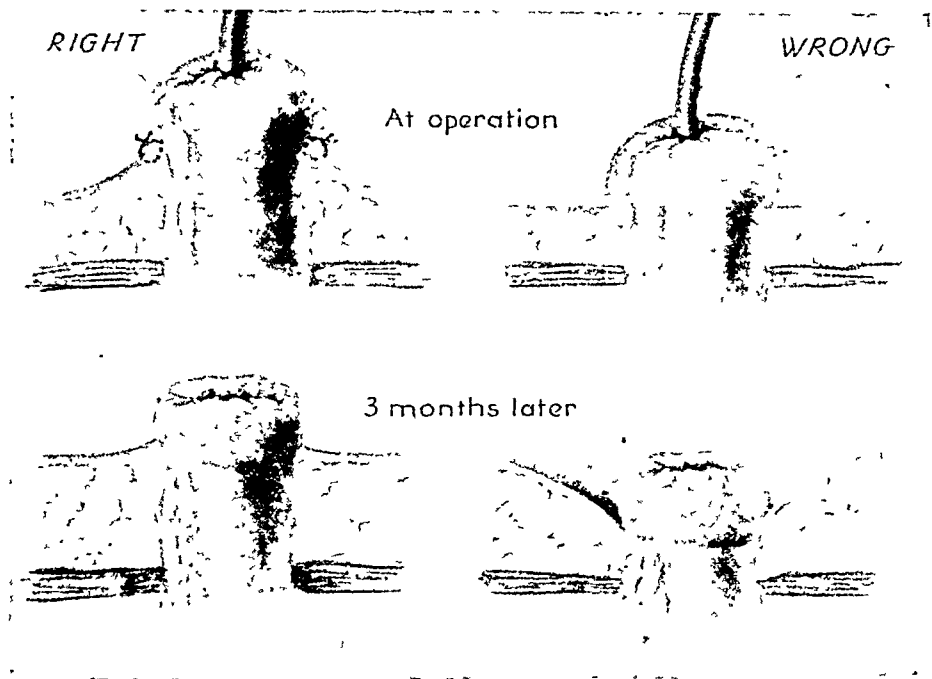


Fig. 7.—At ileostomy the skin is elevated before suture to the bowel. Increase in subcutaneous fat with the usual weight gain then ultimately leaves the patient with the skin flat, so that the bag will fit nicely and excoriation next to the ileum can be avoided. Without this protection, a funnel-shaped depression can defeat efforts to preserve the skin.

Proper choice of time of day, usually three or more hours after eating, so that constant discharge is not occurring, greatly facilitates clean changes of bags.

Thrombophlebitis: Pulmonary embolus has killed two patients here in the last eighteen months, one nine days postoperatively and one preoperatively.* This is such a common complication of the disease that patients are now regularly kept up and active, when possible, up to the time of surgery, and are routinely placed on dicumarol sufficient to keep the prothrombin time twice the control as soon as possible postoperatively.¹⁴

Postoperative weight gain and skin sutures: When management and care are performed as has been described, most patients have returned to the active

*Embolism also killed the only patient who has been subjected to ileostomy (double bared) elsewhere by this method. The patient had had a perforation and had a large mass in the sigmoid region. He died following embolism occurring less than seventy-two hours after operation. Dicumarol had been started at sixty hours. It is possible that the drug should be given preoperatively.

life followed before onset of the disease. The weight gain following ileostomy is prompt and marked. Of thirteen patients in whom proper procedures were employed and data are available, the average weight gain in the three months after surgery was 22.7 per cent of the body weight at surgery. The extremes were no gain and 71 per cent gain.

This weight gain is largely due to deposit of fat between the skin and the deep fascia. The result is likely to lead to bulging of the skin except close to the ileostomy, where the surface will necessarily funnel down to the bowel, which, of course, has not increased in length (Fig. 7). In order to permit a flat skin ultimately, to which an ileostomy bag can be well fitted, it is best at the time of ileostomy to lift the skin out immediately adjacent to the bowel and to suture the two thus (Fig. 7).

COLECTOMY

Indications.—Following successful ileostomy, most of these patients not only improve generally, but have a marked diminution in rectal drainage, often to one-half ounce every day or two. This is a reflection of the improvement usually seen in the colon on proctoscopic and on barium enema x-ray examinations. About half of these individuals, however, continue to have enough trouble to indicate colectomy. The indications have been fully discussed elsewhere.¹ In summary they are: persistence of profuse flow, presence of polyps or actual carcinoma, more than one exacerbation of colitis, or profuse bleeding.

General Procedures.—The improvement following ileostomy usually proceeds for three to four months. In order to take full advantage of it, colectomy is deferred until at least five to six months after ileostomy, when it can be undertaken with minimum risk. At this time the patient is usually in excellent general condition and can tolerate general anesthesia nicely.

Initially colectomies were undertaken in stages, such as recommended by Lahey.⁹ With the improvement in preparation of patients, the freer use of blood and plasma, and the inception of vastly improved anesthetic measures, the policy has shifted to completion of the job in one stage.

In the earlier cases, the terminal ileum, the colon, and the rectum were removed, the rectum usually in a separate stage. Two difficulties arose with proctectomy. In the first place, a draining sinus was prone to persist for months or years in the perineum. In the second place, those males subjected to the operation were found to be incapable of penile erection. Further experience suggests that the rectal pouch can be easily watched from time to time by proctoscope and that it heals fairly often sufficiently to permit consideration of anastomosis to the ileum.

Experience is accumulating to show that it is not possible to determine by barium enema-roentgen study in chronic nonspecific ulcerative colitis if some portions of the colon are normal. Repeatedly, efforts have been made to save portions of the colon on this basis. Except in the rare segmental colitis, no cases have been found in which portions of the colon could be salvaged when x-ray alone indicated them normal. In the rectum and lower sigmoid, proctoscopic examination is reliable. The colon is now removed to the rectosigmoid, therefore, and the rectum observed periodically by proctoscope.

The procedure has been reduced routinely to excision of terminal ileum and colon to the pelvic floor sparing the rectum. With such measures, closure of the stump by Parker-Kerr sutures or the Petz sewing machine and silk mattress sutures was difficult and unsatisfactory. The wall of the rectosigmoid is usually heavily inflamed, edematous, thickened, and friable, rendering inversion virtually impossible by standard methods. Two out of four of the rectums closed

by those methods, before adoption of the present technique, developed pelvic abscesses requiring drainage through the rectum or vagina.

Rectosigmoid Closure.—Because of these difficulties, a closure was devised which would eliminate difficulty with inversion and eliminate the dead space usually remaining between the first and second rows of sutures.

The colon is removed to the apex of the sigmoid in customary fashion, making no effort to peritonealize the lateral gutters. Leaves of peritoneum are elevated from the right and left sides of the mesocolon down to the pelvic floor for subsequent reperitonealization, but the superior hemorrhoidal vascular supply to the rectosigmoid is carefully preserved (Fig. 8). Two heavy ties (No. 9 silk) are placed $1\frac{1}{2}$ cm. apart around the carefully devascularized bowel at about the second sacral level, and the gut is cut between them with the cautery.

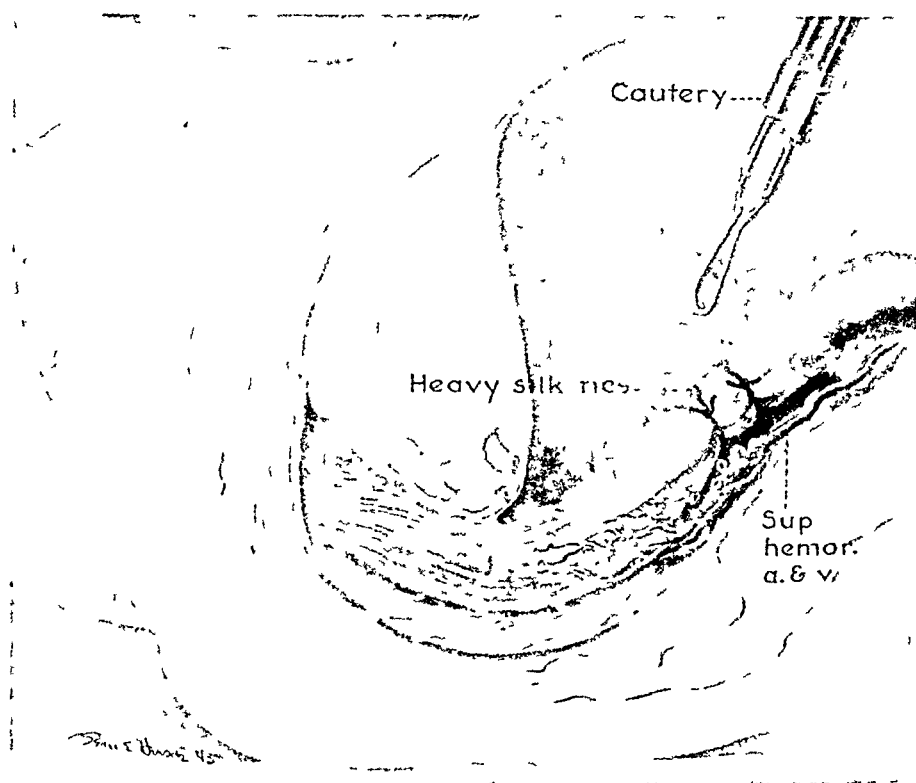


Fig. 8.—Closure of thickened rectal stump in ulcerative colitis. Superior hemorrhoidal blood supply is preserved. Two heavy ties are placed around the carefully cleaned rectosigmoid, 1.5 cm. apart. The bowel is cut between with the cautery.

An assistant now inserts into the rectum from outside the sterile field a brass tube 1 cm. in diameter fitted with a loosely fitting 7 mm. wooden core. This procedure is facilitated by elevation of the hips preoperatively on several folded sheets. This instrument is inserted until the tip can be palpated by the operator from within the abdomen.

Two straight needles are threaded, one on each end of a one-meter piece of No. 30 stainless steel wire. One is inserted through the cut end of the colon and forced well into the wooden core; it passes through the loop of heavy silk which encircles the gut, close to it behind. The second needle passes through the bowel wall anteriorly, but just outside the silk tie, and passes into the core (Fig. 9).

The brass tube is now held in place while the wooden core is withdrawn with the needles. The assistant outside the sterile field can now put tension on the

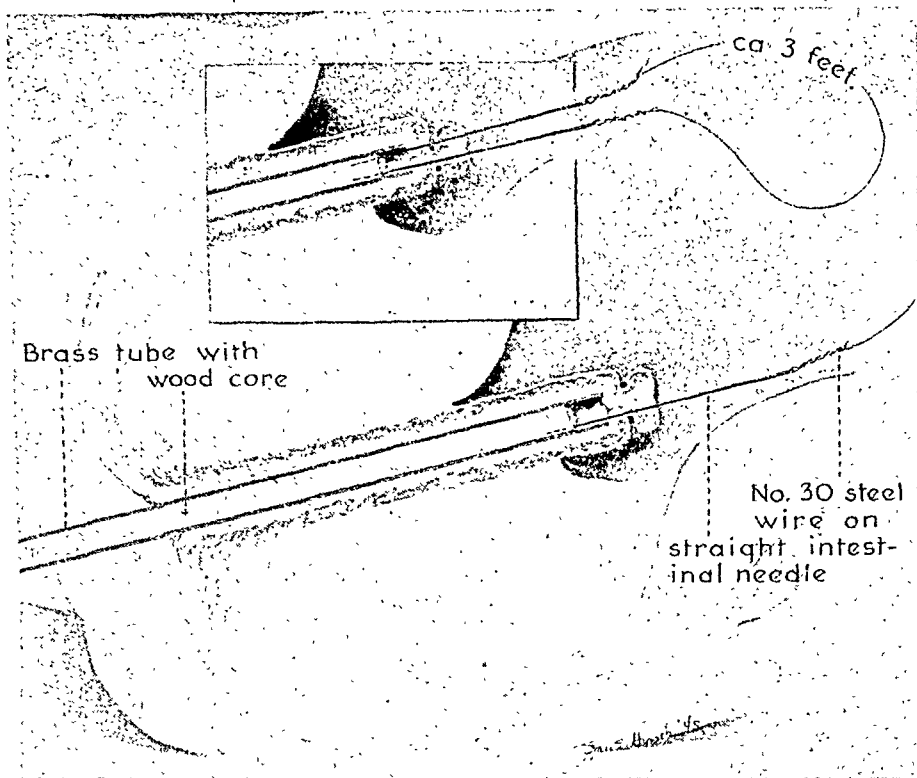


Fig. 9.—Rectal closure in ulcerative colitis. A metal tube with a loose wooden core is inserted from outside the sterile field into the rectum. A 3 foot piece of No. 30 steel wire is fitted with a straight needle on each end. These are passed through the bowel and forced into the wooden core in such a fashion that, when the core is withdrawn, the wire will pull on as much tissue as possible and pass out and through the heavy silk tie.

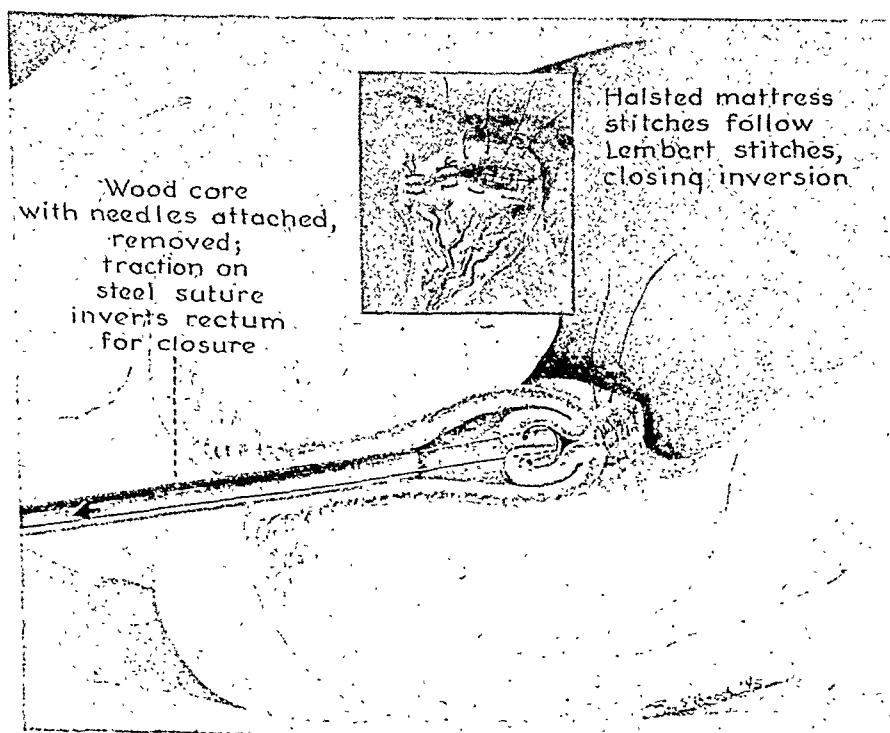


Fig. 10.—Rectal closure in ulcerative colitis. By traction on the wire from below, inversion of the thickened narrow rectum is possible. It is secured by a row of Lembert and a row of Halsted mattress sutures.

ends of the steel wire to accomplish, by use of some force, inversion which would otherwise be impossible. Such tension accomplishes inversion by the employment of sutures in the bowel wall for countertraction. Closure is completed by a row of Lembert silk sutures and another of Halsted mattress silk (No. 4-0 Deknatel). Usually 50 mg. of sulfathiazole are implanted between rows (Fig. 10).

In order to open the contaminated dead space between the encircling tie and the two-layer closure, the encircling silk and much of the enclosed bowel are cut by a sawing motion (that is, similar to use of a Gigli saw) on the two ends of the steel strand by the assistant outside the field. The inverted bowel can now be palpated through the rectal wall to have been turned inside out. No dead space remains, and healing should be uncomplicated (Fig. 11).

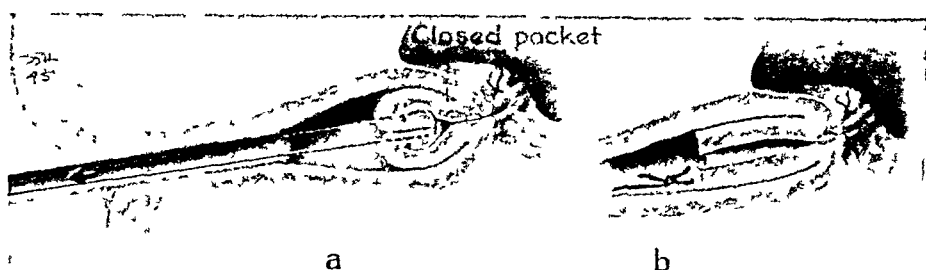


Fig. 11.—Rectal closure in ulcerative colitis. Tension on the rectal wall by the mass of inverted tissue, and the closed contaminated space between the encircling tie and the two-layer closure, are both eliminated by cutting the encircling tie and completely inverting the cut end by means of the steel wire.



Fig. 12—Pelvic floor is reconstituted, using interrupted Halsted mattress silk sutures

The peritoneal floor is refashioned with interrupted Halsted mattress silk sutures, which hold even in case of pus formation, using peritoneum of the bladder in men, or posterior surface of the uterus in women, and the flaps elevated from the mesosigmoid (Fig. 12). Usually about 2 Gm. of sulfathiazole have been implanted beneath the peritoneal closure.

To date, five closures have been accomplished in this fashion. None has had pelvic infection, and the patients usually have gone home within twelve days.*

*Recently a modification of this method has been tested to open the double diaphragm in utilization of the Halsted bulkhead anastomosis to reestablish continuity after resection of a low-lying rectosigmoid carcinoma. The wire kinked and broke, so that the diaphragm had to be punctured with a knife, but a clean anastomosis and primary union resulted.

Risk of Colectomy in Chronic Ulcerative Colitis.—The risk of colectomy in ulcerative colitis is variously estimated.¹⁶ Apparently it is no greater than that of laparotomy. There have been no deaths in this group at the University of Minnesota Hospitals since Jan. 1, 1934. All patients colectomized here for ulcerative colitis in this period are alive at the present time.

RE-ESTABLISHMENT OF CONTINUITY

To date, six patients with ileostomy for chronic ulcerative colitis have had restoration of continuity performed by ileoproctostomy. Four of these were done by Owen H. Wangenstein and two by the author. In general, when the procedure has been reserved for those who develop solid stools from the ileac stoma and who present rectal mucosa normal to proctoscopic study, the patients have remained well without diarrhea. Those who do not satisfy these criteria appear to redevelop diarrhea and ulcerative lesions in the rectum, although the mucosal area involved is too small to interfere appreciably with the patient's general health.

We have had no experience with simple closure of ileostomy at this clinic.

CONCLUSIONS

1. With prompt and proper surgical management, chronic ulcerative colitis is not a disabling disease.

2. Ileostomy is the first surgical procedure in chronic ulcerative colitis almost invariably at the University of Minnesota Hospitals and should not be complicated by any other simultaneous procedures.

3. A method of ileostomy which has proved successful in this reported series of cases is presented. In twenty cases there were one case of prolapse, two cases of recession, two cases of some trouble with skin excoriation, no cases of failure of primary union, no hernias, and two deaths. The deaths occurred from pulmonary embolus in one case and from involvement of ileum, jejunum, and stomach in the other.

4. In the experience at the University of Minnesota Hospitals the Koenig-Rutzen bag offers the only satisfactory method of handling properly constructed ileostomies.

5. Dicumarol postoperatively is given routinely to patients with chronic ulcerative colitis.*

6. Colectomy is done four to six months after ileostomy if there are: repeated exacerbations of colitis, polyps or carcinoma of the colon, profuse drainage, or continued bleeding. The rectum is spared and watched.

7. A method of closing the rectal stump is presented. It appears to be safer than older methods.

8. In selected cases, re-establishment of continuity has been possible by ileoproctostomy and resection of the intervening bowel many months after ileostomy.

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EXTRUSION OF GASTRIC MUCOSA THROUGH THE PYLORUS

REPORT ON TWO PATIENTS TREATED BY PARTIAL GASTRECTOMY

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THE basis for gastrointestinal symptoms is frequently difficult to determine. This is because there is a multiplicity of factors playing a role in the production of symptoms. These factors fall into two groups: those that have a definite demonstrable physical basis and those in which no physical factor is found. Before a patient is placed in the second category, it is important that every diagnostic aid be employed to demonstrate that there is no physical basis for the patient's complaints. At the United States Naval Hospital in Seattle a few patients who had been labeled malingerers were found to have extrusion of gastric mucosa into the pylorus, which was the cause of their symptoms. Since operation these men have been restored to duty.¹⁰

This presentation is concerned with a small group of patients having gastrointestinal disorders which are difficult to diagnose, namely extrusion or prolapse of gastric mucosa into the pylorus causing obstruction. Two patients treated by partial gastrectomy are reported.

According to Meyer and Singer,¹ the first instance of extrusion of gastric mucosa was reported by Von Schmieden² in 1911. Since then the following reports have been made: Eliason and Wright,³ 1925, one; Eliason, Pendergrass, and Wright,⁴ 1926, two; Meyer and Singer,¹ 1931, one; Meyer,⁵ 1935, one; Pendergrass and Andrews,⁶ 1935, three; Rees,⁷ 1937, four, three operated upon; Bohrer and Copleman,⁸ 1938, one, died of complications; Archer and Cooper,⁹ 1939, four. We are reporting two and Commander A. M. French, United States Naval Hospital, Seattle, has described four, as yet not reported. These make a total of twenty-three proved by operation.

Symptoms of extrusion of gastric mucosa into the pylorus are indefinite. This is because it depends upon the degree of obstruction present. Complaints may be classified under four headings.⁷ (1) Periodic upper abdominal distress,

with sensation of fullness in this region; (2) cramplike pains after eating, more pronounced after taking solid foods; (3) vomiting, the last symptom to appear; and (4) loss of weight, the logical result of the first three symptoms. These patients are usually afraid to eat, at first because of pain and later due to vomiting. As the symptoms are intermittent, patients have varying periods in which they feel well; however, the tendency is to become worse.

Radiologic findings are somewhat indefinite.^{3, 4, 6, 7, 11} In a typical case there is a shadow containing a small, opaque streak in the duodenum. This streak differentiates it from tumor. It should be emphasized that the findings under fluoroscopy may be inconstant during any given examination. Radiologic examination is the only method by which diagnosis can be made. The radiologist is likely to miss the diagnosis unless he is aware that such a condition exists and looks for it.

ETIOLOGY

Eliason and Wright³ believe that this condition is the result of chronic inflammation causing hypertrophy of gastric mucosa with extrusion of the mucosa into the pylorus. Rees⁷ is of the opinion that the pathology is due to narrowing of the pyloric outlet following hyperperistalsis in an effort to push the stomach contents through. The condition must not be confused with Billroth's hypertrophy, which is a benign hypertrophic pyloritis. According to Pendergrass,¹² and Archer and Cooper,⁹ bleeding is occasionally associated with this condition, causing secondary anemia. They state that hypertrophy of the gastric mucosa may undergo malignant change.

REPORT OF CASES

CASE 1 (Hospital No. 446341).—Mrs. S. M., a 61-year-old woman presented herself to one of us (I. S.), May 22, 1944, complaining of pain in the epigastrium for the past week. The pain was intermittent and taking food made it worse. It made no difference what kind of food she ate. She had vomited several times.

Past history brought out the following: twenty-five years before she had had cholecystostomy; eight years previously, cholecystectomy; five years before, hysterectomy was performed for bleeding fibroids. The maximum weight had been 204 pounds two years previously. At that time she had attended the diabetic clinic at the King County Hospital. The diabetes mellitus was of a mild degree, and insulin did not have to be administered. The diabetic condition had been under good control until the present symptoms developed.

Physical examination revealed a woman weighing 163 pounds. The skin was clear and there was no evidence of icterus. The blood pressure measured 136/90 mm. of mercury. General examination brought out the following: there was nothing abnormal about the head, neck, or chest; the heart was apparently not enlarged; there were two scars on the abdomen, an upper right rectus incision, and a lower midline incision extending from the umbilicus to the symphysis pubis. Both were well healed and showed no evidence of herniation. There was no evidence of fluid or tumor in the abdomen. Pain in the epigastrium was elicited upon deep palpation. Pelvic examination revealed the uterus to be absent, the cervix present, but with no evidence of pathology. Rectal examination was negative; the extremities were unchanged and the reflexes normal.

Laboratory Examination.—The blood Wassermann was negative. There was no sugar in the urine. Fasting blood sugar revealed the blood level to be 120 mg. per hundred cubic centimeters of blood. The results of gastric analysis were 75 free HCl, total 90. Radiologic examination at this time revealed an "area of roughness in the pyloric end of the stomach." This radiologist concluded that while he could not demonstrate ulcer, it was the most likely diagnosis. Flat plate of the abdomen revealed no evidence of stones in the kidney, ureter, or common duct.

The patient was placed under treatment for ulcer without relief. Codeine sulfate had to be taken frequently to control pain. At times she felt well, and again, especially upon taking solid foods, she had severe pain. However, her appetite was good, but she was afraid to eat. She continued to lose weight.

Oct. 6, 1944, she was referred to another radiologist, who reported that the esophagus showed no abnormality. The one abnormality, as seen at time of fluoroscopy, was extrusion of redundant mucosa in the distal end of the stomach through the pylorus into the base of the cap. The small intestine distal to the duodenum showed no abnormality. The examination was repeated by the same radiologist with the same findings. Examination of the small and large intestines revealed no abnormality.

The symptoms of pain, nausea, and vomiting continued intermittently. Nov. 11, 1944, she was examined by one of us (M. N.) before entering the hospital for operation. Her weight was 134 pounds. At that time no additional physical findings were revealed. Nov. 25, 1944, under combined spinal pontocaine and intravenous sodium pentothal anesthesia, exploration brought out the following: the gall bladder was absent; there were adhesions in this region; the common duct was not dilated. Careful palpation revealed no evidence of stone or obstruction. Aspiration of the common duct revealed normal bile. The liver was not enlarged and showed no gross pathologic change. The uterus was absent. Nothing abnormal was found in the small or large intestine. The spleen was not enlarged. When the stomach was examined it was found to contain a soft, tumorlike mass which could be pushed into the pylorus; otherwise, the viscus was negative.

What Was Done.—Three-fifths of the distal part of the stomach were resected. A retrocolic anastomosis was done according to the Finsterer method. Five grams of sulfathiazole crystals were sprinkled in the upper abdominal cavity and the abdomen was closed without drains. Pathologic examination brought out the following: before fixation of the gross specimen, redundancy of gastric mucosa and almost complete obstruction of the pylorus could be demonstrated. During microscopic examination, section of the pyloric end of the stomach showed the mucosa with a moderate amount of monocytic infiltration between the gland structures. The musculature was normal. Diagnosis was chronic gastritis.

Postoperative convalescence was uneventful. She was discharged to her home on the eleventh postoperative day. On the fifteenth postoperative day she developed a slight icterus which disappeared in five days. This was thought to be due to sulfathiazole. She remained well and was completely relieved of the symptoms until Dec. 28, 1944, when she developed pyelonephritis and diabetes mellitus, and was readmitted to the hospital. The kidney infection was difficult to combat, but she gradually improved and was discharged from the hospital Jan. 30, 1945. She remained well and was relieved of all preoperative symptoms until March 26, 1945, when she developed epigastric pain, nausea, vomiting, and prostration. She was taken to the King County Hospital where, in spite of administration of glucose, plasma, and transfusions, she became progressively worse. The blood protein remained low despite these measures. Generalized edema developed. She was unconscious for days at a time. Clinical jaundice was present throughout her stay in the hospital until she died, April 29, 1945. Post-mortem examination revealed subacute hepatitis, fibrosis of the pancreas, terminal bronchopneumonia, general anasarca, and large decubitus ulcers. The stomach showed no change except subtotal resection. There was no evidence of ulcer or obstruction.

CASE 2 (Hospital No. 45948).—J. V., a 42-year-old fisherman, was first seen May 7, 1943, at which time he complained of epigastric pain and nausea of one week's duration. He had had no previous stomach trouble, no melena or change in bowel habits. Past history revealed that in 1928 he had had an appendectomy and at the age of 15 a mastoidectomy of the right side.

Physical examination at that time revealed a man weighing 210 pounds, which was his usual weight, and measuring six feet in height. There was a mastoidectomy scar on the right side; otherwise, there was nothing abnormal about the head, neck, or chest; the blood pressure measured 124/86 mm. of mercury; pulse was 70; heart was not enlarged; there was a scar on the right side of the abdomen which was healed well; there was slight tenderness to deep palpation in the epigastrium. No fluid or tumor masses were felt in the abdomen. There were no hernias. Genitals were normal. The extremities were unchanged. The reflexes were normal.

Laboratory Examination.—The blood Wassermann was negative; blood count and urinalysis were within normal limits; gastric analysis free HCl 60, total 85. Radiologic examination, May 8, 1943, revealed a small penetrating ulcer on the lesser curvature of the stomach at the angle. The duodenal cap was normal. The small intestine distal to the duodenum was normal throughout.

The patient was placed under treatment for ulcer by one of us (I. S.), including alkalis and antispasmodics. Radiologic examination, June 19, 1943, by the same radiologist revealed no evidence of ulcer.

The patient was next seen Feb. 12, 1945, at which time he complained of pain, nausea, and vomiting, especially after eating solid foods. Because of this condition he had become afraid to eat. While he was relieved by food at the time he had gastric ulcer in 1943, food now definitely made him worse. He had lost twenty-four pounds within a period of six weeks, which he stated was due mainly to the fact that he was afraid to eat. Physical examination brought out the following: weight, 186 pounds; there was nothing abnormal about the head, neck, chest, or abdomen except that there was slight tenderness to deep palpation in the epigastrium. The blood pressure measured 120/84 mm. of mercury. The temperature was normal; blood count and urinalysis were within normal limits. Radiologic examination at this time revealed: The barium passed readily through the esophagus, which appeared normal. The stomach showed definite prepyloric induration strongly suggestive of early carcinoma. There was marked concavity of the base of the bulb similar to the appearance produced by prolapse of the gastric mucosa, and it was possible that all the findings were due to such a condition. Carcinoma seemed more probable, however. At the end of three hours the stomach was almost empty and the head of the meal was in the cecum.

The patient was operated upon Feb. 23, 1945, by one of us (M. N.), at which time the following was found: in the prepyloric region there was a tumorlike mass which was firm and which could be pushed into the pylorus. At the angle there was a small scar, probably representing a healed gastric ulcer. Further exploration of the abdomen revealed no evidence of gall bladder or biliary tract disease, and there was nothing abnormal found in the small or large bowel.

What Was Done.—Under combined spinal pontocaine and intravenous sodium pentothal anesthesia, an upper left paramedian incision was made. Approximately three-fifths of the distal end of the stomach were resected and an anticolie anastomosis was done. The abdomen was closed without drains. Examination of the removed segment of the stomach before fixation revealed marked hypertrophy of the prepyloric gastric mucosa, and this could be easily pushed into the pylorus causing complete obstruction. There was no evidence of ulcer of the stomach. During histologic examination, section made from the stomach wall near the pylorus showed a large amount of monocytic infiltration, germinal center formation, and destruction of much of the mucosa due to the infiltration of monocytic cells. The whole thing indicated a marked gastritis at this end of the stomach. Diagnosis was gastritis.

The patient made a good recovery and was discharged to his home on the tenth post-operative day. Since that time he has been completely relieved of the preoperative symptoms of pain, nausea, and vomiting. He has gained ten pounds in weight and feels well.

DISCUSSION

At present the surgical treatment recommended for this condition is resection of the redundant gastric mucosa.⁷⁻⁹ This is done by making an incision through the anterior wall of the stomach and placing a finger into the pylorus through this opening. A second incision is then made into the pylorus. The redundant gastric mucosa is excised and the incision in the mucosa is sutured. All bleeding vessels are ligated and the incision in the pylorus is closed. Some surgeons apparently close this in a longitudinal manner and some transversely. Finally the incision in the stomach is closed.

Rees⁷ reports a patient on whom he performed posterior gastrojejunostomy with no relief. This is what one would expect, as the peristaltic action of the stomach would still push the redundant mucosa into the pylorus. Three years later resection of gastric mucosa was done without relief. This is evidently the only patient reported who did not obtain relief from resection of gastric mucosa. Rees states that "... the closure of the gastric mucosa did not hold entirely," as revealed by subsequent x-ray findings, and attributes failure to this cause.

Gastric resection was done in our first case because of the high acidity. It was feared that ulcer might develop at the side of the excision of the gastric mucosa or that closure of mucosa would not hold. It was also deemed advisable to perform an operation that would give the patient the best possible chance for permanent relief. In Case 2, gastric resection was done in view of the history of gastric ulcer, high acidity, and the radiologist's report of possible car-

cinoma. Besides, subtotal gastrectomy for benign lesions is now being done with a great deal of safety so that the added risk of gastrectomy over excision of the mucosa is minimal. In young patients with moderate acidity, excision of mucosa is no doubt the operation of choice.

It is our opinion that redundancy of gastric mucosa is not as uncommon as reports would indicate. Some patients who have mild gastric symptoms where nothing definite is found may be suffering from this condition. Every abdominal surgeon has no doubt noted redundancy of prepyloric gastric mucosa when palpating normal stomachs. Therefore, medical management of these cases should be instituted, especially if the symptoms are not severe. This should be done even if the actual condition has been demonstrated radiologically. In this connection, Bockus¹³ in his book, *Gastro-Enterology*, stated, "Moderate redundancy of the pyloric mucosa is probably not uncommon but, unless it is associated with severe gastritis or actual prolapse of the gastric mucosa into the duodenum in sufficient quantity to interfere with evacuation of the stomach contents, symptoms are not produced."

The pathologic study of the tissues removed in our cases would indicate that the condition is probably due to inflammation. There was nothing to indicate a narrowing due to hypertrophy or contraction of the musculature in the pyloric region. In Case 2, especially, the inflammatory reaction was marked.

Although we are not responsible for the radiologic diagnoses in these cases, attention should be called to the fact that many radiologists are not aware of the existence of this condition and therefore are not on the lookout for it. The first radiologist who examined the patient in Case 1 was apparently unable to interpret what he saw. Consequently the diagnosis was missed, although the condition was probably observed by him. On this subject Bockus¹³ stated, "When complete prolapse into the duodenum occurs, the differentiation between pedunculated tumor and prolapsing gastric mucosa will often be impossible and operation may be necessary. If there is a large defect in the pyloric canal and a negative shadow in the duodenal bulb, the condition may not be distinguished from that of pyloric ulcer, hypertrophic gastritis, or carcinoma."

It will be noted that we have used "extrusion" instead of "prolapse" to designate the condition present in these cases. The term "prolapse" is defined in the dictionary¹⁴ as: "The falling down or sinking of a part or viscus." Therefore, it does not describe this condition accurately. "Extrusion," as defined by Dorland¹⁴ is, "A pushing out; a forcing out or expulsion"; consequently it conveys correctly the pathologic physiology present in these cases, as it is due to the peristaltic action of the stomach pushing the hypertrophic redundant gastric mucosa into the pylorus that causes obstruction and symptoms.

SUMMARY AND CONCLUSION

1. Two cases of extrusion of gastric mucosa into the pylorus causing intermittent obstruction with marked loss of weight are reported. Partial gastric resection was done in both cases with satisfactory results, although one patient died five months after surgery from hepatitis.

2. The condition is undoubtedly more prevalent than reports would indicate. Diagnosis is made by the roentgenologist who must be aware of and look for this condition.

3. In mild cases, medical management should be instituted before surgery is recommended. Two operative procedures are at the surgeon's command: re-

section of redundant gastric mucosa or partial gastric resection. The choice of the procedure should be determined by the age of the patient, the gastric acidity, and the judgment and skill of the surgeon.

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INTUSSUSCEPTION IN ADULTS

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STATISTICAL data appear to show that of all intussusceptions the incidence in adults is about 5 per cent.

In infants, according to Perrin and Lindsay, 78.5 per cent occur in the sixth and seventh months of the first year, especially in boys. The ileocecal and ileocolic varieties are the most common at all ages, but enteric intussusception occurs more frequently in adults than in children.

Incidence.—A comparison of the incidence of intussusception according to Perrin and Lindsay and Fitzwilliams is shown in Table I.

It is common medical experience that there are, as a rule, no discoverable etiologic factors in infants, while in adults there is usually an organic lesion, a benign or malignant tumor, as the basic cause.

Other provocative influences are (1) typhoid ulcers, (2) tuberculous ulcers, (3) dysentery, (4) acute appendicitis, (5) Meckel's diverticulum, (6) a con-

TABLE I. INCIDENCE.

PERRIN AND LINDSAY (4,000 CASES) (PER CENT)		FITZWILLIAMS (1,000 CASES) (PER CENT)
Ileocecal	46.5	60.8
Ileocolic	37.6	25.6
Enteric	10.1	0.0
Colic	5.6	7.3

genital ileal band, (7) a submucous lipoma of the ileum, (8) a foreign body, (9) a sudden radical dietary change (Moore), or (10) neoplasms.

Enlarged lymphoid patches not infrequently cause intussusception, and an instance in point appears to be the high incidence of the ileocecal variety, with the presence of large Peyer's patches. The detrusor action of the terminal ileum and the greater size of the colon have been regarded as other probable causes. Lymph patches or polyps, it is maintained, irritate the intestine and thus provoke peristalsis. Wardill¹ suggested "fixed spasm" as the prime mover.

"Primary" intussusception does not commonly occur in the adult in contradistinction to the condition in infancy because lymphoid tissue becomes progressively reduced with age and also because the lumen of the intestine in the adult is relatively larger.

The majority of intussusceptions are of the enterocolic variety, and it is in the ileocecal zone that considerable anatomic alteration in the size of the gut takes place.

The Anatomic Causation.—It is a widely accepted view that an intussusception is induced by irregular and increased intestinal peristalsis due to some irritant or lesion in the wall or lumen of the intestine. The condition in adults is rarely functional.

Physiologic Causation.—Fraser² proved that the innervation of the ileocecal zone is distinctive in that the nerve supply of the ileum is sympathetic and parasympathetic; the cecum receives a supply of sympathetic nerves only. An explanation is thus found for the descending peristaltic irregularity.

Pathologic Causation.—Intussusception at times occurs during an attack of enteritis and there is a strong probability that the swollen Peyer's patches may induce the hyperperistalsis. (It has been shown frequently that there is a distinct concurrence of ileocecal tuberculous lesions and intussusception.)

Intussusception of the gastrointestinal tract may take place anywhere between the stomach and the rectum. The large bowel is the most frequent site of involvement in adults because benign and malignant growths, particularly the former, are more common there than in any other part of the gastrointestinal tract.

An intussusception usually forms a rather firm sausage-shaped swelling composed of three concentrically arranged tubes or layers—the afferent, efferent, and ensheathing. The first two form the intussusceptum and meet at the apex, or most distal part of the invagination; the ensheathing layer constitutes the intussusciens and joins the returning layer at the neck of the intussusception. With the growth, in length, of the invagination, the mesentery is progressively drawn into the intussusceptum where it is caught between the entering and returning layers on the concave side.

The constriction and torsion of the mesentery induce congestion from pressure on the veins, which is most obvious at the apex and in the adjacent part

of the returning layer. The apical part particularly swells to a great extent. This is due to the extravasation of blood and mucus obstructing the lumen. Adhesions subsequently form between the apposed serous surfaces of the entering and returning layers.

Varieties of Intussusceptions.—Intussusception may be single or compound. In the latter, the primary invagination is surrounded by a secondary, which may in turn be surrounded by a tertiary, invagination.

Intussusception is ordinarily classified in accordance with the anatomic features. Perrin and Lindsay³ suggested that the classification be in two groups: (1) ileocecal and (2) ileocolic.

In the first variety the ileocecal valve forms the peak of the intussusception, while in the second, the invagination begins in the ileum adjacent to the valve and passes through it into the cecum.

There are, in reality, three forms:

1. Enteric (10 to 15 per cent), in which the small intestine invaginates. This form is prevalent in older children and adults. It is usually of organic causation. In the ileo-ileal variety only the small intestine is involved; it may progress to become an ileo-ileocolic variety, ordinarily discoverable in children.

2. Colic (5 to 10 per cent), in which the colon ensheaths (therefore, colocolic). This variety occurs in elderly persons. A not infrequent cause is a polypoid carcinoma or a benign polypoid growth.

3. Enterocolic (75 to 80 per cent), in which the ileum invaginates into the colon. This is common in infants. In this category there are three distinct subvarieties:

- (a) Ileocecal, the ileum passing into the colon, with the ileocecal valve as the fixed vertex.

- (b) Ileocolic, beginning in the terminal ileum and then progressing into the colon.

- (c) Enteric ileocecal, starting as an enteric intussusception, becoming wedged in the ileocecal valve, which it pushes forward, and then advancing as an ileocecal intussusception, with the valve at its summit.

Retrograde Intussusception.—A retrograde bowel ensheathment is said to occur only in the small intestine at the time of death. It is, however, seen occasionally during life and may occur at a gastroenterostomy opening.

Jejunogastric Intussusception.—When a gastroenterostomy has both an afferent and efferent jejunal loop, the following three varieties of jejunogastric intussusception may, on rare occasions, occur as complications within a few days or years after the anastomosis:

1. The afferent loop solely may intussuscept into the stomach.

2. The efferent loop may retrograde and stop short of or pass through the gastroenterostomy stoma.

3. The afferent and efferent loops may intussuscept into the stomach.

Etiology of Jejunogastric Intussusception.—Pregnancy at one time was considered an embryologic factor, but the majority of reported cases of jejunogastric intussusception had no association with that condition and many have been described as occurring in men.

In most instances the afferent and efferent intestinal loops passed into the stomach.

Symptoms of Intussusception.—In adults the symptoms of intussusception are not as prominent as in infants. They are vague in most instances, with

signs of mild recurrent obstructions associated with symptoms of the provoking cause.

There are coliclike abdominal pains, nausea, vomiting, obstipation, and bloody stools.

A mass in the abdomen is commonly not palpable.

In jejunal intussusception, symptoms usually intermittent may be present for months or years. There is always a history of upper abdominal pain, especially after meals. Nausea and vomiting are common. Blood in the stools is not as common in jejunal intussusception.

The abdomen is not distended early, but becomes manifestly so as the obstruction progresses.

On auscultation exaggerated peristaltic sounds may be heard, until complete obstruction, when one elicits the significant silent abdomen.

Palpation usually reveals tenderness and rigidity over the involved area. (The first may be absent as well as the second, due to the fact that the parietal peritoneum is not irritated and that protection is afforded by the ensheathing intussusciptions.)

A tumor mass may be felt, with or without anesthesia. It is sausage shaped and lies transversely across and subjacent to the abdominal wall.

In early cases a barium enema may be given at low pressure and an attempt should be made to reduce the mass under fluoroscopic control. This is often surprisingly successful in the colic or enterocolic varieties.

It is almost impossible to reduce the enteric variety merely by rectal injection.

Diagnosis and Differential Diagnosis.—The differential diagnosis is often confusing, with the exception of those instances in which a palpable tumor is present. Here the sudden concurrence of an abdominal tumor, usually in the right lower quadrant, with the symptoms of intestinal obstruction, is suggestive but not absolutely indicative of intussusception. A large bowel malignancy, for example, may simulate intussusception.

The diagnosis is mainly roentgenographic or surgical.

Diagnosis of Jejuno gastric Intussusception.—If the afferent loop is intussuscepted, the patient will as a rule complain of (1) postprandial epigastric pain with colicky exacerbations and (2) bilious vomiting.

The roentgenograms in most instances will reveal a distended afferent loop. The opaque meal will demonstrate a rounded filling defect in the stomach (due to the intussusception) upon which a relief pattern, the jejunal plicae, will be observable.

If the efferent loop takes a retrograde intussusceptal course, an acute high small bowel obstruction results with consequent colicky abdominal pain and the vomiting of gastric, then bilious, and finally intestinal contents.

If the afferent and efferent loops intussuscept into the stomach, an acute, high obstruction obviously results.

The frequent difficult differential diagnosis is jejuno gastric intussusception is due to the fact that the symptoms are interpreted as the result of other possible complications of the gastroenterostomy—stomal inflammation or ulceration, for example, or complications due to the primary causative factor, a leaking perforative or bleeding ulcer.

The differential diagnosis in intussusception must likewise be made from (1) Henoch's purpura, (2) acute enterocolitis, (3) simple colic, and (4) tuberculous mesenteric glands.

The Roentgenographic Examination.—The barium enema and examination of the abdomen without opaque media are used to diagnose intussusception. The opaque or barium enema is preferred by many roentgenologists.

When an acute abdominal condition is present or suggested by the symptoms, an examination without opaque media is of course preferable.

In subacute and chronic intussusception in adults it will be found that the combined contrast meal and enema examinations will prove most helpful in diagnosis.

The roentgenograms will reveal (1) dilatation of the gut above the invaginated part, (2) sudden narrowing over a variable length of gut, which is the central cylinder of the intussusception, and (3) various degrees of the "ensheathment sign."

The plain film manifestations of enterocolic intussusception are (1) absence of the mottled appearance of the cecum, due to slight gas and fecal content, (2) collection of gas-distended small gut loops in the region normally occupied by the cecum, (3) homogeneous opacity of the intussusceptum, (4) peripheral concentric "ringing" by translucent gas, (5) conical stenosis of the small gut as it enters the intussusception, and (6) direct visualization of the tumor provoking the intussusception.

Treatment.—

Palliative: Palliative treatment is justifiable only under the most exceptional circumstances. An early intussusception can sometimes be completely reduced with a pressure enema of water or air. This method is dangerous and is better employed in infants and older children.

Surgical: An immediate surgical operation should be performed as soon as the diagnosis is made. Ether anesthesia is best avoided. Spinal anesthesia is preferred. A one-stage operation may be performed.

When a hot pack fails to effect reduction, an attempt should be made, according to Cope,⁴ to insert a finger into the neck of the intussusception (between the entering and returning layers) and to sweep it around in this space; the adhesions are thus broken down and reduction facilitated. If this maneuver proves ineffective, a rubber-covered forceps is placed in the neck as far as it is safely possible and the blades are opened in several places. This procedure serves the dual purpose of dilating the neck and of breaking down recent adhesions.

If the aforementioned methods fail, the neck should be divided for an inch or more along the antimesenteric border with a pair of forceps. The incision is closed transversely to avoid narrowing of the lumen of the gut.

If the large intestine is the intussusception site, graded operations are preferable. Attempts at reduction and pressure should be made over the peak of the intussusception, with simultaneous light traction on the proximal free bowel.

In some cases of irreducible, uncomplicated intussusceptions a short-circuiting operation may be performed. If the intestine is irreducible and gangrenous, one of the following expedients may be tried:

(1) Resection, with end-to-end, side-to-side, or end-to-side anastomosis.

(2) Jesset's operation—removal, solely, of the invaginated part of the bowel through the encompassing part of the intestine. After the incision in the bowel is made, the invaginated part is withdrawn in a downward direction as far as possible and cut away. Circular suturing closes the cut margins of the amputated, gangrenous bowel. The ensheathing part of the bowel is

then approximated and united by a through-and-through continuous suture whereon a Lembert stitch is placed. A few interrupted sutures close the neck of the intussusception.

The circumjacent and contiguous parts are next explored to discover a tumor. If it is not found at the apex of the intussusception, the bowel should be further examined, both proximally and distally.

The Management of Prolapsed Sigmoidal Intussusception.—The patient is placed in steep Trendelenburg position and a spinal anesthesia is given.

A firm rubber tube, about one inch in diameter, is passed through the lumen of the invagination and the prolapsed sigmoid to a level a few inches beyond the site of involvement; a tight rubber band is now passed over the invaginated sigmoid to the level of origin of the invagination. The intussuscepted sigmoid subsequently sloughs off because of the two constricting devices and an anastomosis is thus established.

Treatment of Jejuno-gastric Intussusception.—The treatment of jejuno-gastric intussusception is always surgical. If the afferent loop is involved, reduction is effected by slight traction. A recurrence is prevented either by anchoring the afferent loop to the stomach or to the transverse mesocolon or by undoing the gastroenterostomy. Sometimes a gastrectomy, in part, including resection of the anastomosis, may be deemed advisable.

If the efferent loop is entangled, reduction by traction may be found adequate, but in delayed cases, with gangrene, resection, obviously, must be carried out.

When both intestinal loops are involved, reduction is by traction.

Prognosis.—Sometimes there is a spontaneous reduction of an acute intussusception of the recurrent variety. The prognosis, when palliative measures prove ineffective, depends, of course, upon early and quick surgical care.

CASE REPORTS

CASE 1.—S. S., a 49-year-old white man, a taxicab driver, was admitted to the hospital in February, 1930, complaining of cramplike circumumbilical pains, nausea, and almost complete obstipation of one week's duration. He had taken several enemas without result. Ten years previously he had had an appendectomy and gastric operation for ulcer; the type of operation was unknown.

Present Illness.—The day previous to admission, the patient's pains became more severe and he vomitted a black-colored material on several occasions. Shortly after admission he vomitted foul, fecal-smelling material.

Physical Examination.—On physical examination, he presented a picture of profound shock. He was extremely pallid and peaked and appeared in extremis. General physical examination was negative with the exception of the abdomen. The latter presented a right lower rectus and left upper rectus scar and was not distended. Tenderness was present all over the abdomen and was most marked in the right lower quadrant where marked rebound tenderness was present. The temperature was 101.4° F., pulse, 120; blood pressure, 88/70; white blood cells, 15,400 with 86 per cent polymorphonuclear cells. The urine contained a faint trace of albumin with many hyaline and granular casts.

Surgical Procedure.—In view of the patient's precarious condition, no extensive operative procedure was contemplated. That he was suffering from an acute intestinal obstruction was obvious; a scaphoid abdomen was present and there were fecal vomiting and almost no pulse. Nevertheless his poor condition demanded an emergency procedure. The origin of the obstruction was believed to be traceable to adhesions from his previous laparotomies. The left upper abdomen was opened through a very small incision measuring about two and one-half inches in length, parallel to the rib margin, the first distended loop of jejunum secured, and a Senn jejunostomy performed with marsupialization of the bowel to the parietal peritoneum. A large quantity of free serous fluid was noted in the abdomen. One hour after the operation the patient showed marvelous improvement. He felt better and the

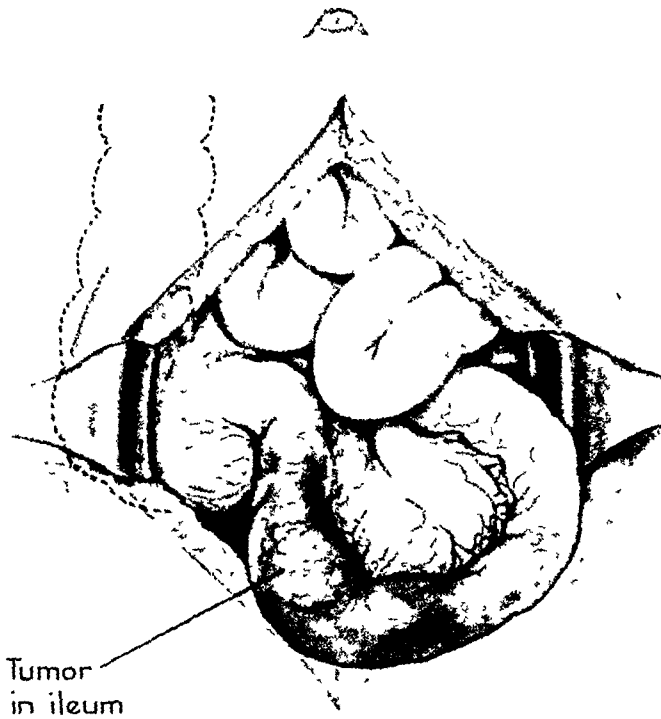


Fig 1 (Case 1).—Adenomatous polyp of ileum

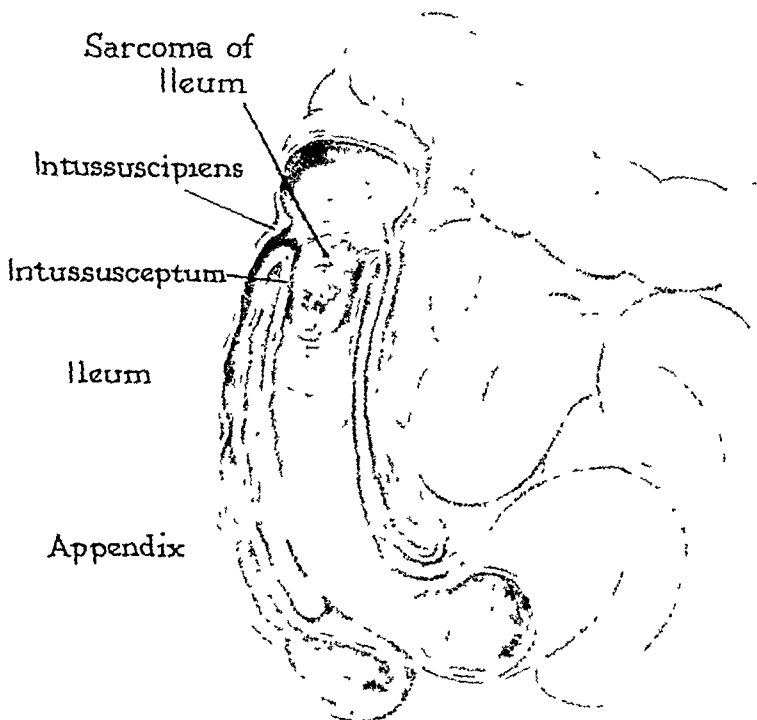


Fig. 2 (Cases 2 and 3).—Sarcoma of intussusceptum (blunt)

pulse was of good quality. There was no vomiting or nausea. Postoperatively as well as preoperatively the patient was given large quantities of saline by hypodermoclysis and intravenously. Drainage was rather profuse through the jejunostomy tube, moderate quantities of food were retained by mouth, and there were occasional small bowel movements and flatus passed. The cramplike abdominal pains persisted, however, at first less severe but gradually increasing in severity. Twelve days postoperatively the abdomen was opened again, through a lower midline incision. The small intestine was markedly distended and there was found a large intussusception of the ileum through the ileocecal valve into the cecum and ascending colon, involving about 25 cm. of intestine. The intussusception was easily reduced by slowly milking out the intussusceptum in the accepted manner. The ileum was found to be almost black, markedly inflamed, edematous, and lusterless and showed evidence of beginning gangrene. A few inches from the ileocecal valve was felt a firm mass inside the lumen of the ileum close to the apex of the intussusception. The ileum with the encircling mass was brought outside the abdominal wall and a first stage Mikulicz operation performed. In this case an artificial anus was established through the small bowel. Due consideration and thought were given to the resultant liquid continuous fecal discharge and possible progressive malnutrition. However, the patient's condition, together with the pathologic findings, required heroic yet unorthodox measures. Nevertheless, the end justified the means. Drainage through the previous jejunostomy was maintained through a catheter. Three days later, that portion of ileum which had previously been brought outside the abdomen was resected to within a short distance from the abdominal wall by cautery. Nine days later a spur clamp was applied in the usual manner and twenty-five days following the first stage the continuity of the ileum was re-established. The postoperative course was entirely uneventful. Three days after the final closure the patient had his first normal bowel movement, and two weeks following, was discharged.

Pathology.—The resected intestine was 19 cm. in length. At operation there was found a cauliflower growth within the lumen of the gut, about 4 cm. in diameter, attached to the intestinal wall by a short pedicle. About 2 cm. proximal to this was found a second polypoid mass about 3 cm. in diameter, discolored and red, with a smooth surface. This growth could not be felt at the time of operation.

The surrounding intestine was quite edematous. Microscopic examination showed the intestinal mucosa to be the seat of a localized area of hyperplasia of the glands from which there extended a mass of mucoid substance in which were found strands of deep-staining epithelial cells, distorted in outline. Although the superficial portion of the nodule showed no tendency to alveolar arrangement of the epithelial cells, the portion adjacent to the adjoining normal mucosa was definitely adenomatous in character. There was an associated polymorphonuclear cell and mononuclear cell infiltration with numerous plasma cells found at the base of the nodule in the surrounding intestinal wall. The edema was limited to the superficial portion of the mucosa. The pathologist's diagnosis was benign adenomatous polyp with mucoid degeneration.⁴

CASE 2.—G. H., a 68-year-old white man, a painter, was admitted to the hospital Oct. 25, 1939. His chief complaint was paraumbilical pain radiating to the right lower abdominal quadrant.

Family and Past Personal History.—Histories were irrelevant.

Present Illness.—The present illness began about one month previously. The patient experienced paraumbilical, cramplike pain radiating to the right lower quadrant. There was no nausea or vomiting. The attacks lasted several minutes and gradually disappeared. For four or five days prior to admission pain was almost continuous. The bowel movements were regular and there was no melena.

Physical Examination.—A complete physical examination disclosed no abnormalities, with the exception of a tender mass palpable in the right lower abdominal quadrant, adjacent to the right side of the umbilicus. The mass was not easily displaceable. The blood pressure was 142/100; hemoglobin, 85 per cent; red blood cells, 4,700,000; white blood cells, 6,000; polymorphonuclears, 80 per cent; no basophilic stippling of red blood cells.

Operation.—October 27, two days after admission, an exploratory laparotomy was performed, through a right rectus incision, under spinal anesthesia (procaine).

Surgical Data.—An intussusception of the lower ileum into the cecum and ascending colon was discovered, with some degree of inflammation about the involved loops. The intussusception was released with gentle pressure from the intussusciptens; this maneuver exposed a firm, indurated ileal tumor on the antimesenteric border, the size approximating a fifty-cent coin.

Impression.—The impression was sarcoma of the ileum.

Surgical Procedure.—The lower ileum for an extent of six inches and the lower ascending colon and cecum were mobilized and exteriorized (Lahey technique). The protruding loop was then resected, forming a double-barreled enterostomy. The abdomen was closed in layers and petroleum jelly gauze was inserted into the wound around the exposed intestine.

Pathologic Report.—A small-cell sarcoma was found infiltrating the muscularis and serosa.

Postsurgical Therapy.—Hypodermoclyses of glucose in saline solution were given. Drainage through the colostomy was profuse. The general condition of patient was satisfactory. November 5 (ninth postsurgical day), a spur clamp was applied; this fell spontaneously out of the wound November 11 (six days after application).

Examination several days later revealed presence of a small spur, and a clamp was reapplied November 20; it fell out again November 23.

The patient was prepared for a third stage Mikulicz operation, or closure of the enterostomy, which was carried out, under spinal anesthesia, November 24.

Postsurgical Course.—At first the postsurgical course was stormy. The pulse was weak, thin, and rapid. The blood pressure was 78/60. Perspiration was profuse and the extremities cold. The patient was placed in the Trendelenburg position and intravenous infusion of 10 per cent glucose was slowly administered. There was good response in two hours and the general condition of the patient gradually improved. A small amount of drainage, fecal in character, appeared through the abdominal wound but stopped in a week.

The patient was well four years after the operation.

CASE 3.—A. T., a white housewife aged 36 years, was admitted to the hospital Dec. 16, 1933. She complained of intermittent abdominal cramps, loss of weight, and weakness of one and one-half years' duration. The cramps were at first generalized, then of increased severity, localizing around the umbilicus; they gradually diminished in severity. Relief frequently was obtained by passage of flatus. The last, most severe attack began one week prior to admission and was accompanied by nausea and a vomiting spell. The weight loss was 80 pounds in eighteen months.

On admission the patient was restless, moving from side to side, with thighs flexed. The temperature was 103° F.; pulse, 114; and blood pressure, 120/80.

Physical Examination.—The abdomen was moderately spastic. A slightly tender mass, about 7 cm. in diameter, was palpable to right side of umbilicus.

Surgical Procedure.—The following day the abdomen was explored through a right rectus incision. There was serosanguineous fluid in the peritoneal cavity, and an irreducible intussusception of the ileum into the colon as far as the distal third of the transverse part was discovered. There were involved loops of intestine and mesentery, extremely congested, edematous, and adherent. The affected bowel was mobilized, brought to the surface, and resected. The wound was closed about the two intestinal barrels. The excised mass of intestine, 34 cm. long and 8 cm. wide, included cecum, appendix, and about 30 cm. of invaginated ileum.

Second Postsurgical Day.—A rubber drainage tube was inserted into the proximal opening. The abdomen was soft. The temperature varied between 101 and 102° F.; pulse, 100 to 120.

A spur clamp was inserted December 26 (nine days after enterocolectomy) and was removed December 31.

Anastomosis was completed by a third stage Mikulicz procedure Jan. 4, 1934. Four days later the patient had the first spontaneous bowel movement. Small fecal discharge appeared in the abdominal wound and continued less than a week.

The patient was discharged from the hospital Jan. 15, 1934, in good general condition.

Pathology.—Intussusception with areas of necrosis in mucosa and muscularis of ileum and colon was found. There was no evidence of tumor formation.

CASE 4.—H. B., a white man, aged 33 years, was admitted to the hospital Feb. 12, 1936. His chief complaint was spasmodic abdominal pain of six months' duration recurring at intervals and radiating to right and lower abdominal quadrants. The pain at first occurred daily; at the time of admission it occurred on alternate days but was of greater intensity. There was no relationship to food intake. There was some loss of weight and the appetite was poor due to pain.

Physical Examination.—A slightly movable mass was found in left upper abdominal quadrant.

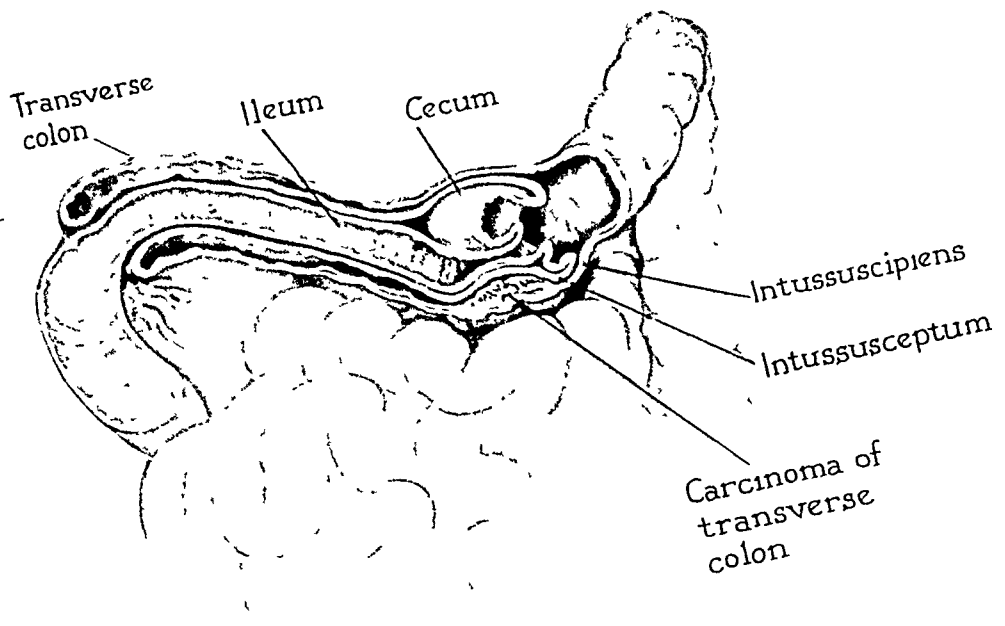


Fig. 3 (Case 1) —Carcinoma of intussusciens

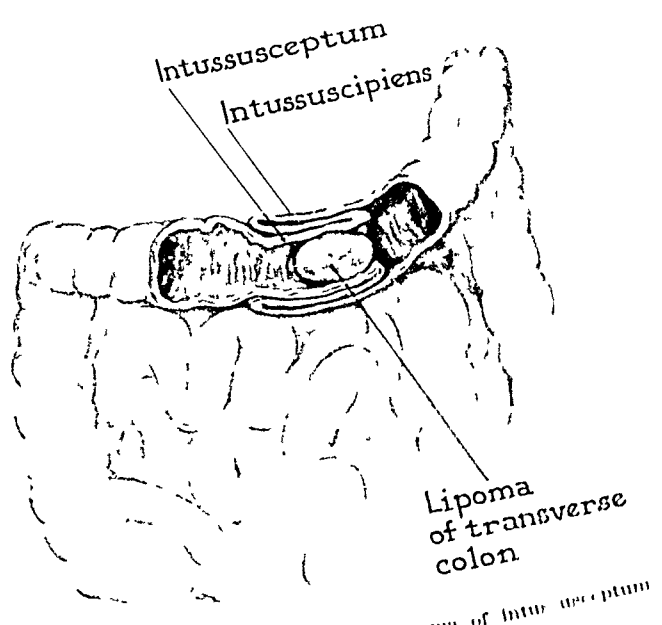


Fig. 4 (Case 5) —Submucous lipoma of intussusceptum

Operation.—An operation was performed Feb. 14, 1936, using an upper left rectus incision.

Surgical Data.—A large mass, with evidence of subacute or chronic inflammation, involved a large extent of the transverse colon. The cecum and appendix were missing. The lower ileum, with cecum and ascending colon, were found intussuscepted into the transverse colon up to the splenic flexure. Intussusciptions, with lost luster, showed extreme hypertrophy. The apex of the intussusception (situated near the splenic flexure), on palpation, gave the impression of a mass. There were edema and congestion of the mesentery of the transverse colon and small amount of fluid present in the peritoneal cavity.

Surgical Procedure.—The mass was reduced by careful pressure on the intussusciptions, distal to apex of intussusception, thereby freeing the bowel. Induration and apparent loss of viability of cecum and ascending colon suggested the removal of this part of the intestine, including the lower ileum. The condition of the patient made it expedient to carry out ileocelectomy, in part, by a multiple-stage procedure. The lower six inches of ileum and entire ascending colon, and part of transverse colon, were brought into the wound in the manner of the Mikulicz operation.

Pathology.—Carcinoma of splenic flexure of colon was found.

Comment.—This case was of special interest because there was a carcinoma in the intussusciptions and not in the intussusception.

The patient made uneventful recovery.

CASE 5.—J. A., a 39-year-old white man, a plumber, was admitted to the hospital Feb. 8, 1941. His chief complaint was abdominal cramps of three weeks' duration, with nausea and gradual loss of weight.

Physical Examination.—A mass in the left upper abdominal quadrant was discovered.

Roentgenographic Examination.—There was an obstruction near the splenic flexure.

Surgical Data.—A first stage Mikulicz operation was performed Feb. 16, 1941. Intussusception of the ascending colon into the transverse colon as far as the splenic flexure was found. There was extreme edema of walls of transverse colon, as well as of gastrocolic omentum, with moderate thrombosis of gastrocolic vessels.

Surgical Procedure.—The intussusception was reduced, revealing extreme induration and swelling at the apex of the intussusception. The necrotic condition of the bowel required a multiple-stage resection of the diseased part of the transverse colon. The transverse colon was exteriorized up to the splenic flexure and removed by cautery (Feb. 20, 1941) four days after the first stage procedure. A spur clamp was applied immediately, but it was found necessary to apply another spur clamp six days later in order to remove the residual spur about one inch in length. Four days after the first stage procedure a second one was carried out, with removal of exteriorized loop. A spur clamp was applied March 15, 1941. March 22, 1941 (five weeks after the first procedure), continuity of the bowel was re-established.

Union was per primam, except for a small serous collection subcutaneously at the upper angle of the wound. The patient recovered.

Pathology.—A submucous lipoma of the mid-part of the transverse colon was found.

CASE 6.—H. H., a 60-year-old white man, was admitted to the hospital March 16, 1942, with a history of repeated attacks of abdominal cramps radiating to right loin. He complained of constipation, slight weight loss during the previous two months, and anorexia.

Present Illness.—For the sixteen hours prior to admission the patient had had severe abdominal pain, cramplike in character, especially on the right side. He had had no bowel movement for thirty-six hours, but in the few hours before admission had noticed a slight sanguineous mucoid discharge from the anus.

Physical Examination.—A slightly distended abdomen with a moderately tender, slightly movable, elongated mass in right mid-abdomen was disclosed.

Surgical Data.—A right rectus incision was made March 16, 1942.

Findings.—An ileocolic intussusception with marked discoloration, edema, and dullness of ascending colon was found. The reduced intussusciption was almost black, and at a point four inches proximal to the ileocecal valve there was a firm egg-shaped mass about three-fourths by one and one-half inches, apparently adherent to the anterior ileal wall. There was a moderate free serosanguineous fluid in the peritoneal cavity. The mesentery of the lower ileum showed several thrombosed vessels.

Surgical Procedure.—In view of the pathology found, it was deemed advisable to do a side-to-side ileotransverse colostomy and a primary resection of the lower ileum and ascending colon.

The patient made an uneventful recovery, and one year later was entirely symptom free.

Pathology.—Sarcoma of lower ileum was found.

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AN IMPROVED METHOD FOR EXTRAPERITONEAL CLOSURE OF COLOSTOMY

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IN ORDER for the surgical closure of a colostomy to be successful, it is necessary to overcome many obstacles which are not present in most other operative procedures. The entire operation for re-establishing the continuity of the bowel must be performed in an infected field and, therefore, healing must take place in the presence of inflammation in an individual whose resistance has been lowered by the primary lesion for which the colostomy was originally performed. All of these factors are detrimental to firm wound healing and favor the development of complications.

Therefore, the purposes of this paper are to present an improved method for extraperitoneal closure of colostomy and to demonstrate its advantages in an analysis of seventy-five consecutive cases over a ten-year period.

TECHNIQUE

The operative steps which are preliminary to the actual closure of the colostomy, as illustrated in Fig. 1 (A to F), are as follows:

An elliptical skin incision is made, longitudinally around the colostomy down to the anterior rectus sheath, leaving a narrow rim of skin attached to the stoma for traction (A and B). The subcutaneous tissue is carefully dissected from the anterior rectus sheath and bowel wall, leaving a one-inch margin of cleaned fascia around the colostomy (C and D). A circumferential incision is then made through the anterior rectus sheath leaving a one fourth inch rim of fascia attached to the bowel which will be subsequently utilized as an extra layer in the closure (E). The excess bowel and attached rim of skin are now removed (F).

The operative steps involved in the actual closure of the colostomy, as illustrated in Fig. 1 (G to L), are as follows:

Closure of the bowel in its transverse axis is accomplished by the use of the Connell stitch reinforced by the Lembert stitch (G and H). The circumferential rim of fascia

(described previously and illustrated in Fig. 1E) is approximated longitudinally by a continuous suture (I). This is the most important step because it provides an additional firm, supportive layer for the closure and also relieves tension on the intestinal suture lines beneath, which favors rapid healing and thereby reduces the incidence of local complications such as fecal fistula, wound infection, dehiscence, and hernia. Tension sutures are then inserted at one-inch intervals through the skin, passing beneath the margins of the anterior rectus sheath (J). The anterior rectus sheath is approximated by mattress sutures so spaced as to allow for drainage between them (K). A Penrose drain is placed in the depth of the wound and protrudes from both ends of the incision, after which the tension sutures are tied to approximate the skin and subcutaneous tissue (L).

The average operating time for this procedure was found to be thirty-five minutes.

ANALYSIS OF SEVENTY-FIVE CASES

In this series (Table I) it was found that the average age was 51 years and that females predominated by 12 per cent. Furthermore, of the lesions necessitating colostomy, the malignant predominated over the benign in the ratio of 2.5:1.

TABLE I. INCIDENCE OF SEVENTY-FIVE COLOSTOMY CLOSURES

AGE	SEX		PATHOLOGIC LESION			
		NO.	%		NO.	%
Extremes	Males	33	44	Malignant	53	70.6
23-75 yr.	Females	42	56	Nonmalignant	22	29.4
Average				Polyp	5	
51 yr.				Diverticulitis	6	
				Chronic volvulus	4	
				Stricture	4	
				Ulcerative colitis	2	
				Regional enteritis	1	

In an analysis of the relative time factors incident to closure of these colostomies at their various locations (Table II), it was found that the average interval between the performing of the colostomy and its closure was twelve weeks, but that this varied with the pathologic lesion so that it was six weeks in the group of malignancies and twenty-six weeks in the benign. This time factor was increased in the latter (enumerated in Table I) because of the necessity of specific interval therapy before the colostomy was closed, and was found to be fifty-one weeks in diverticulitis and approximately fifteen weeks in each of the remaining lesions in this group. It was further revealed that the minimum time interval between the colostomy and its closure was three weeks, allowing ten days before the spur was crushed and another ten days before the colostomy was closed. This occurred only in the group of malignancies.

Following colostomy closure, in all locations it was found that normal stools appeared after an average of five days and that the average hospital stay was three weeks. A significant finding was that the period required for complete healing of the operative site averaged four weeks. Further analysis revealed

TABLE II. TIME FACTORS RELATED TO COLOSTOMY CLOSURES

LOCATION	NO. OF CASES	PREPARATION PERIOD		CONVALESCENT PERIOD		
		TIME BETWEEN COLOSTOMY AND SPUR CRUSH (WEEKS)	SPUR CRUSH AND CLOSURE (WEEKS)	PERIOD BEFORE NORMAL STOOLS (DAYS)	HOSPITAL STAY AFTER CLOSURE (WEEKS)	PERIOD FOR COMPLETE HEALING (WEEKS)
Sigmoid	31	9	5	5	3	4
Transverse	29	5	4	5	3	5
Descending	10	5	5	4	3	4
Cecum	5	-	-	5	3	2
Average		7	5	5	3	4

that 94.6 per cent (seventy-one cases) were healed within five weeks, of which 66.6 per cent (fifty cases) required two weeks, 17.4 per cent (thirteen cases) required three weeks, and only 10.6 per cent (eight cases) required five weeks.

The results in this series are shown in Table III. Primary healing occurred in sixty-one cases (81.3 per cent). There were ten instances (13.3 per cent) of fecal drainage. Of these, six healed without additional surgery within five

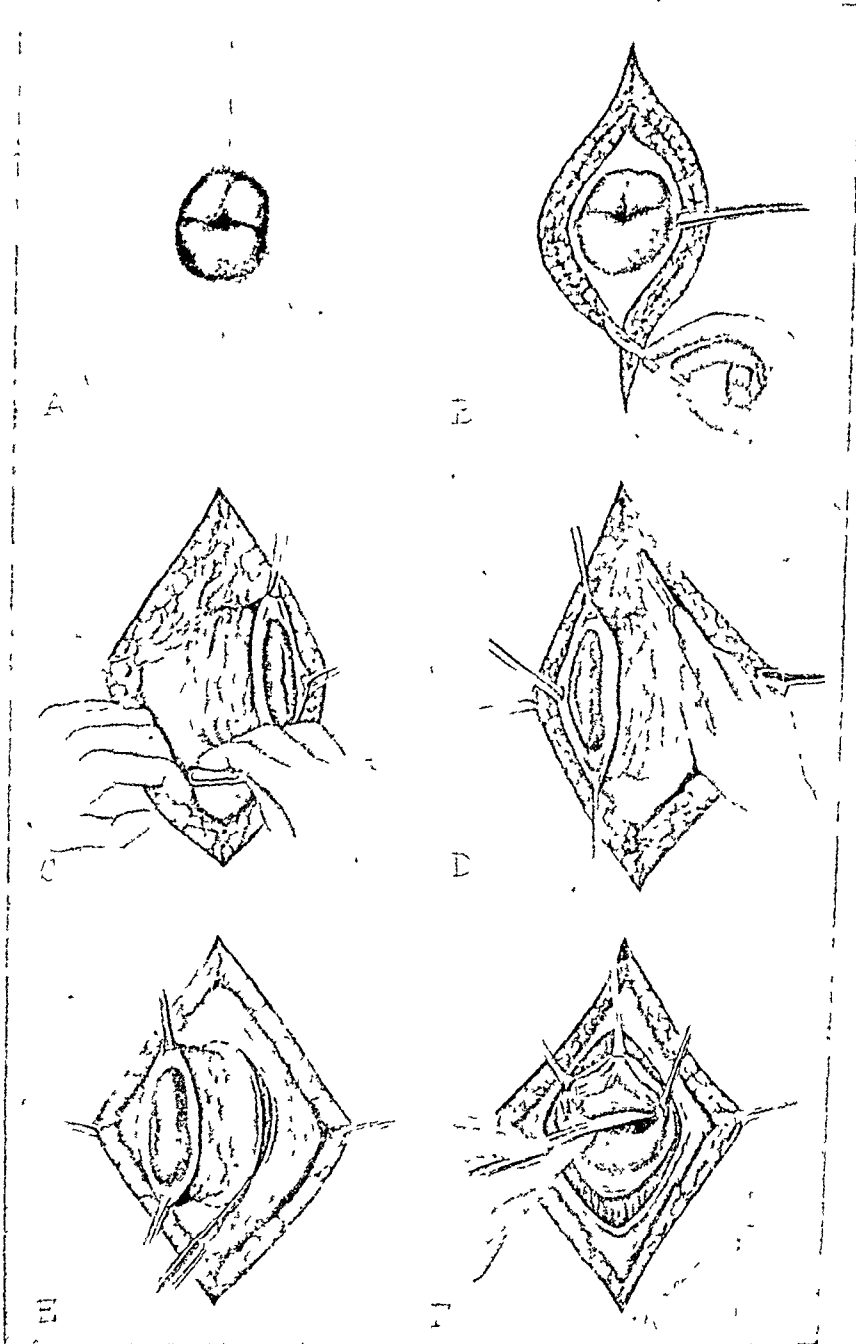


Fig. 1 A to F.—Operative steps preliminary to the actual closure of the colostomy. *A*, Colostomy with healed original incision. *B*, Elliptical incision around colostomy down to anterior rectus sheath, leaving narrow rim of skin attached. *C* and *D*, Dissection of subcutaneous tissue from anterior rectus sheath and bowel wall leaving one inch margin of cleared fascia around the colostomy. *E*, Circumferential incision through anterior rectus sheath leaving a one-fourth inch rim of fascia attached to bowel. *F*, Excision of rim of skin and adjacent excess mucous membrane from the colostomy stoma.

weeks, and two in six months. One persisted for one year, at which time the tract was dilated sufficiently to permit further crushing of the spur which was followed by complete healing in seven weeks. The remaining case, of five months' duration, necessitated secondary operative closure after the residual spur was crushed; healing then took place in three weeks.

Although some degree of inflammatory reaction occurred in all the wounds in this series, in only four cases (5.3 per cent) did it extend beyond the usual

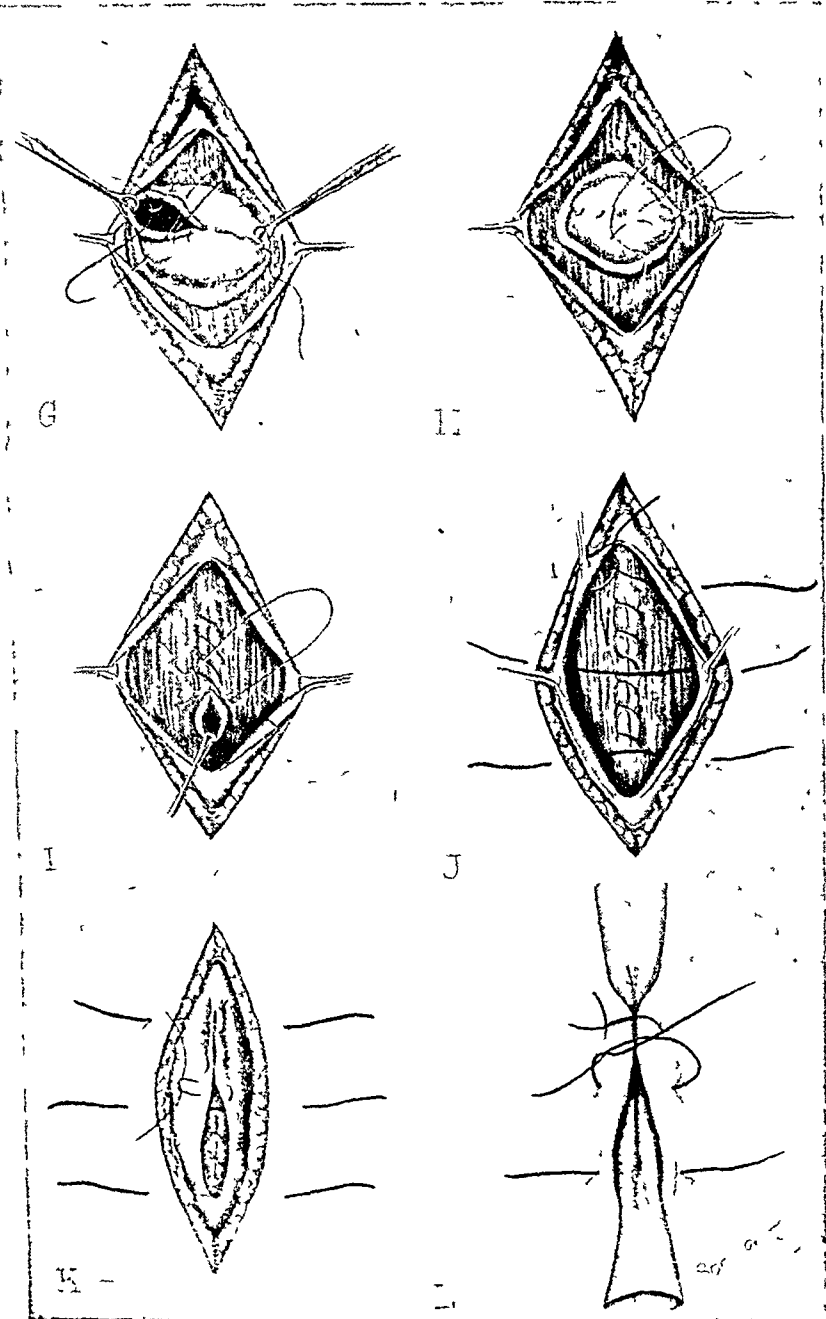


Fig. 1 G to L.—Operative steps in the actual closure of the colostomy. G and H, Closure of bowel in its transverse axis by the Connell stitch overlaid by the Lambert stitch. I, Circumferential rim of rectus fascia approximated longitudinally by a continuous suture. J, Tension sutures inserted through skin, passing beneath margins of anterior rectus sheath. K, Anterior rectus sheath closed by mattress sutures. L, Tension sutures approximating skin and subcutaneous tissue; Penrose drain protruding from both ends of incision.

TABLE III. RESULTS IN SEVENTY-FIVE COLOSTOMY CLOSURES

	NO.	%	CECUM NO.	TRANS- VERSE NO.	DESCEND- ING NO.	SIGMOID NO.
Primary healing	61	81.3	5	22	9	25
Fecal drainage with delayed healing	8	10.6		4	1	3
Fecal drainage requiring secondary spur crush	1	1.3				1
Fecal drainage requiring secondary spur crush and operative closure	1	1.3		1		
Wound cellulitis without fecal drain- age	4	5.3		2		2

five- to seven-day period, and in no instance was surgical interference necessary. The average time for the cellulitis to subside in these four cases was three weeks.

There were no deaths in this series attributable to complications resulting from closure of the colostomy. However, one death occurred on the twenty-sixth postoperative day due to uncontrollable hemorrhage from a coexisting carcinoma of the stomach as proved by autopsy.

SUMMARY AND CONCLUSIONS

A technique for extraperitoneal closure of colostomy, as employed in seventy-five consecutive cases, is described and illustrated. The keystone of this method is a fascial rim of external rectus sheath which is left adherent to the bowel wall and is utilized as an extra layer in the closure. This added, firm support relieves tension on, and enhances healing of, the intestinal suture lines beneath, thereby minimizing complications.

In an analysis of this series we have found this method to have the advantages of being safe and easily performed with a minimum of complications.

DYNAMICS OF BILIARY DRAINAGE

ITS RELATION TO CHOLANGITIS AND PANCREATITIS FROM STRICTURE OF THE AMPULLA OF VATER

MAJOR JOHN M. MCGOWAN,* MEDICAL CORPS, ARMY OF THE UNITED STATES

THE purpose of this presentation is twofold. First, it demonstrates how a minor stricture of the ampulla of Vater can lead to a series of pathologicophysiology disturbances involving the pancreatic and biliary systems. Second, it affords an excellent opportunity for a step-by step study of the therapeutic measures based on physiology necessary to restore conditions to normal.

Following surgical removal of the gall bladder, the patient's condition is very often no better than before the operation. The poor results reported following biliary surgery can be explained on two bases. First, an incorrect diagnosis may have been made preoperatively. A gall bladder removed for complaints based on pathology in another organ or on psychoneurosis can be of no benefit

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to the patient. Furthermore, a young woman from whom a normally functioning gall bladder has been removed is left with a biliary tract which has not had time to accustom itself to the absence of the pressure-regulating mechanism of the gall bladder. A whole series of symptoms may develop in connection with the biliary system which the patient did not have prior to operation. Second, even after a diseased gall bladder is removed, continued symptoms may follow because of inability of the surgeon to pay attention to the physiology of the biliary and pancreatic systems. The actual cholecystectomy is only a part of the treatment for the patient's condition. The liver, pancreas, and extrahepatic biliary tract must be carefully studied for evidence of pathology and treated accordingly.

Following removal of the gall bladder, the postoperative care of the patient begins in the operating room. One of the most important things in this connection is the T-tube drainage of the common bile duct. The indications for opening the common bile duct at the time of operation have been clearly defined by numerous writers and are generally accepted. Some of these indications are: a history of repeated chills or jaundice, the presence of palpable stones in the common bile duct, pancreatitis, a markedly dilated duct. When the duct has been opened and a thorough search for stones made, a T tube should always be inserted for prolonged postoperative biliary drainage.

Besides its therapeutic benefits the T tube serves as a means for studying the biliary and pancreatic systems. T-tube studies are usually begun two weeks after the operation. These consist of pressure and roentgenologic studies. In a previous communication² it was shown that duodenal spasm is a very important factor in preventing bile from running into the duodenum. The resulting back pressure in the common duct often leads to pain. This duodenal spasm was shown to be aggravated by morphine and to be completely relieved by amyl nitrite and nitroglycerin. The case referred to in this report is not, however, one in which duodenal spasm is a prime factor. It is a case of pancreatitis, cholangitis, and cholecystitis, all believed to be due to a stricture of the ampulla of Vater at the duodenal mucosa.

RESTING INTRABILIARY PRESSURE

The method of intrabiliary pressure studies has been previously reported.¹ The apparatus essentially consists of a spinal fluid manometer connected to the T tube in the patient's bile duct. Between the two is a glass Y tube through which saline solution may be added to the apparatus from an ordinary intravenous bottle. The patient is in a prone position in bed. The zero level of the manometer is placed at the level of the xiphoid. The resting intrabiliary pressure is an index of the degree of obstruction to the flow of bile into the duodenum. The pressure normally runs from 0 to 30 mm. of water above the xiphoid level. If there is more pressure than this, the cause must be sought. It may be due to spasm, stricture, edema, pancreatitis, or stones. In the case of spasm the pressure is promptly reduced by inhalation of amyl nitrite.³ Four deep inhalations should be taken by the patient immediately after the ampule is broken. In some cases, the spasm is superimposed on some organic cause, in which case the pressure will be only partially relieved by this method. Cholangiographic studies will determine whether or not there is obstruction from pancreatitis, stone, or stricture. Spasm may also be detected by this method. However, the degree of obstruction can be determined only by pressure studies. The cholangiogram in Fig. 1B indicates that there is obstruction at the lower

end of the common bile duct. Because this disappears in Fig. 1C, one may assume that this obstruction is from a spasm. Roentgenologically, this spasm appears to be of severe degree. However, the pressure studies show that this spasm represents only 50 mm. of water pressure. Since the secretion pressure of the liver is around 300 mm. of water, this degree of obstruction offers relatively little resistance to the flow of bile into the duodenum.

PERFUSION PAIN LEVEL

When the common bile duct is perfused with saline solution at increasing pressures, there comes a point when the patient experiences a sensation of discomfort. The pressure reading at this point is referred to as the perfusion pain level. This is measured in the following manner. A pressure apparatus is connected to the T tube. The system is filled with saline solution from an intravenous bottle. The intravenous bottle is then lowered until the level of solution in the bottle is the same as that in the manometer. The tubing connecting the bottle with the system is left open. The intravenous bottle is then gradually elevated. This results in gradually increasing pressure in the bile ducts and manometer. If no pain is experienced at 700 mm. water pressure, no further pressure is added. The first uncomfortable sensation which the patient feels, whether it be that of distention or actual pain, is used as an index of the pain level. The perfusion pain level is believed to be an index of the degree of inflammation within the biliary tract. It is very common to find a perfusion pain level of around 70 mm. of water three weeks after operation. With continued T-tube drainage the bile duct will become more resistant to pressure so that at the end of two to three months it will tolerate 500 to 700 mm. water pressure before pain is produced in the same individual. If the T tube should be removed when the pain level is low, one might expect that the patient would continue to have pain. If, on the other hand, the pain level is 500 mm. of water pressure, one would not expect that patient to suffer from postcholecystectomy pain because the secretion pressure of the liver is only 300 mm. of water, leaving a margin of 200 mm. water pressure before the pain level could be reached under normal circumstances.

After the pain level is determined, the patient is given $\frac{1}{6}$ gr. morphine to test how much pressure will develop with duodenal spasm. This also serves as an index of the possibility of future postcholecystectomy pain. The amount of pressure produced by morphine spasm varies greatly between patients. An older woman, past the menopause, will frequently have a morphine pressure rise of no more than 50 mm. of water pressure. Such a patient would not be expected to suffer from biliary dyskinesia since this pressure would produce pain in only the very rare case of a patient with an extremely low pain level. On the other hand, if a morphine spasm produces a pressure rise of 300 mm. water as frequently occurs in young women, one would expect that patient to have attacks of postcholecystectomy pain. Such attacks can be relieved by inhalation of amyl nitrite or sublingual administration of nitroglycerin.

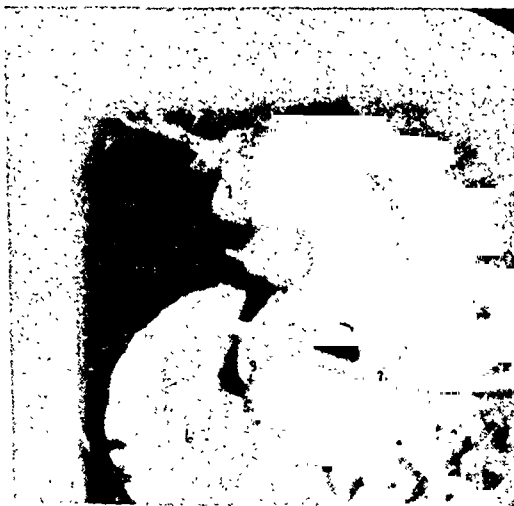
Fig. 1A shows a common duct with some narrowing at the lower end. This narrowing is not sufficient to produce any obstruction to the flow of bile. The resting pressure level in this instance was zero. Although roentgenologically there is some narrowing at the lower end of the bile duct due to a moderate degree of spasm of the duodenum, this is not sufficient to impede the flow of bile into the duodenum at a rate equal to that produced by the liver. The morphine response as indicated in Fig. 1B would lead one to believe that this



A.



B.



C.

FIG. 1.—1, Common bile duct; 2, hepatic duct; 3, point at which the lower end of the ampulla of Vater begins to tunnel the musculature of the duodenal wall; 4, pancreatic duct; 5, common bile duct; 6, duodenum; 7, duodenal tube passed through the nose; 8, T tube in common duct.

A. This shows a moderate degree of spasm of the duodenum. The intramural portion of the common bile duct between 3 and 5 is definitely narrowed. The intramural portion of the pancreatic duct between 4 and 5 shows a narrowing for a shorter distance than that of the common bile duct since it tunnels the duodenum at a right angle rather than obliquely. The fact that the media regurgitates from the common bile duct to the pancreatic duct shows that there is some obstruction at the ampulla of Vater. This could be the nature of a fibrosis. A spastic duodenum would add to this narrowing since it would cause the folds of the duodenum to overlap each other. The muscle spasm of the duodenal wall, however, would not directly encourage regurgitation into the pancreatic duct of bile in this case since the pancreatic duct tunnels the duodenal wall independently of the common bile duct. Note also that there is no regurgitation of barium into the stomach. On the other hand, the barium is being carried at regular intervals downward into the jejunum, a condition which exists where there is not much spasm of the duodenum and probably not much irritability of the biliary tract from infection or otherwise.

B. This was taken ten minutes after subcutaneous administration of morphine, gr. 1/6. The duodenum is now in complete spasm. The lower end of the common bile duct is completely shut off as the result of this. There is regurgitation of barium through the pylorus into the stomach as indicated by the rugal markings above 7. This indicates a relaxed pylorus. The condition in which a spasm of the second portion of the duodenum is associated with a reciprocal relaxation of the pylorus occurs very frequently. This is the beginning of the vomit reflex; it is associated with antiperistalsis of the duodenum.

C. This was taken two minutes after inhalation of amyl nitrate. Note the complete relaxation of the duodenum and the freedom with which the media runs from the common duct into the duodenum. Note that there is a slight regurgitation of media into the pancreatic duct indicating that there is some narrowing at the ampulla of Vater other than spasm, probably a fibrosis as a result of a previous duodenitis. Note that there is no reflux of barium into the stomach. The pyloric tone has recovered. Peristalsis now is in a downward direction toward the jejunum.

spasm was of a severe nature. However, pressure studies show that this only produces an obstruction sufficient to elevate the intrabiliary pressure to 50 mm. of water, well below the secretion pressure of the liver. This patient would not be expected to have any further trouble from biliary dyskinesia or the so-called postcholecystectomy syndrome particularly since the pain level is 500 mm. of water pressure. However, if the pain level were to be decreased markedly by cholangitis and the resting intrabiliary pressure increased by some organic condition such as inflammation of the head of the pancreas, one might expect the pain to occur in this case. Such a possibility is preventable by prolonged intrabiliary drainage, as will be later shown.

X-RAY OF THE BILIARY TRACT

X-ray of the biliary tract is done by injecting diodrast into the common bile duct through the T tube. The relation between the biliary tract and duodenum may be studied at the same time by injecting barium into the duodenum through an indwelling duodenal tube. In this way the relationship between the common bile duct, pancreatic duct, and duodenum can be studied. The diodrast is injected slowly until one feels a sensation of pressure against the plunger of the syringe, a total of 10 c.c. is usually enough. The injection is then stopped and the x-ray taken. At the same time, 60 c.c. of a thin solution of barium are injected through the duodenal tube into the duodenum. If the patient experiences pain at any time, the injection is stopped and the picture immediately taken. A series of three pictures are usually taken, one with the patient in the resting state, one following injection of morphine by ten minutes, and a third following deep inhalation of amyl nitrite by one minute. Cholangiographic studies will reveal the presence of stone, stricture, spasm, or pancreatitis.

Fig. 1A is a combined cholangiogram and duodenogram taken with the patient at rest. This shows a moderate degree of spasm of the duodenum indicated by a narrowing of this organ. The common bile duct enters the duodenum diagonally, showing a definite narrowing in the intramural portion of the common bile duct. There is considerable regurgitation of media into the pancreas. The pancreatic duct enters the duodenal wall in a different spot from that of the common bile duct. The intramural portion of the pancreatic duct is shorter since it enters the duodenum at a right angle. Since the two ducts tunnel the duodenal wall separately, one may assume that the regurgitation of media from the common bile duct into the pancreatic duct is due to some obstruction at the ampulla of Vater. This is due to a narrowing of the opening in the duodenal mucosa in this area.

It is believed that this stricture is the first lesion in the chain of events, resulting in regurgitation of bile into the pancreas producing pancreatitis. Following injection of morphine, in Fig. 1B, there is no regurgitation into the pancreatic duct. The reason for this is that the spasm of the duodenal wall has separated these two ducts. Fig. 1C shows a completely relaxed duodenum. The media runs freely from the common bile duct. Again there is some regurgitation into the pancreatic duct, indicating that spasm was not a factor in the production of this chain of pathologic disturbances.

I have made similar studies on several hundred cases over the past ten years. The results will be reported later. These studies indicate that one should leave the T tube in place until the following criteria have been satisfied.

1. The resting intrabiliary pressure must not be over 30 mm.
2. The perfusion pain pressure should be as high as 500 mm. water or better.

3. Roentgenograms of the common bile duct should show a free flow of media from the common bile duct into the duodenum with no evidence of stones or obstruction from edema or pancreatitis.

4. Two weeks following operation the T tube should be clamped at increasing periods of time starting with one-half hour twice daily and increasing by one hour per day. When the tube is being clamped off twenty-four hours of the day, one should wait another three weeks with a symptom-free patient before the tube is removed. At any time the patient has symptoms, the tube should be opened.

In this particular case there was a recurrence of pain of a biliary nature situated in the right upper quadrant of the abdomen, radiating around the subcostal margin and into the scapular regions ten days after the tube was clamped continuously. This attack was accompanied by chills and fever. There was prompt relief when the tube was opened. Continuous drainage was then instituted for another week. Gradual clamping was started again with permanent beneficial effects. After three weeks of having the tube clamped off all the time, it was removed. The patient has had no recurrence of symptoms since that time.

CASE REPORT

A 39-year-old white woman, a civilian dependent, was admitted to the Ashburn General Hospital, McKinney, Texas, May 28, 1944. Chief complaints were: (1) Pains in the right upper quadrant of the abdomen radiating into the scapular region, of one and one-half year's duration; (2) repeated attacks of diarrhea accompanied by blood and pus in the stool and repeated abscesses of the ischiorectal region for the past two years; and (3) intermittent chills and fever of one and one-half year's duration.

Past History.—The patient had typhoid fever in early childhood. At the age of 13 and again at the age of 18, she had malaria. In August, 1943, she had an attack of malaria; parasites were found in the blood. There was a history of chills and fever in 1939, diagnosed as pyelitis. In the years 1942 and 1943 she had repeated ischiorectal abscesses which were incised and drained. She was left with a persistent fistula-in-ano which was excised April 20, 1944, in a civilian hospital. The wound from this operation continued to drain until her admission to this hospital.

History of Illness at Time of Admission.—One and one-half years before admission the patient began to suffer from sharp pains in the right upper quadrant of the abdomen, fifteen minutes after meals. The patient usually vomited, with complete relief. Pain radiated through to the right scapular region. Because of the inability to retain food, the patient's weight decreased from 180 to 130 pounds.

Physical Examination.—On admission the abdomen was flat. There was some tenderness in the epigastrium and in the right upper quadrant over the gall bladder region. The patient was in such a poor state of nutrition at the time of admission that it was deemed inadvisable to give her a dye in order to x-ray the gall bladder. A flat plate of the abdomen taken at that time was negative. There were healing wounds in the region of the anus, the site of previous operations for fistula-in-ano.

Progress in Hospital.—The patient was put on bed rest and bland diet on admission. She improved considerably. The discharge of blood and pus from the rectum continued. At 4:00 A.M., June 7, 1944, the patient developed a sudden severe pain in the right upper quadrant of the abdomen. This was more severe than it had been on any previous occasion. It kept her awake the remainder of the night. She vomited considerably. At 9 A.M. the white blood count was 15,000. Physical examination at that time revealed considerable tenderness over the gall bladder with a moderate degree of spasm of the muscles in this region. At 3 P.M. of the same day the pains became even worse and were more diffuse over the abdomen. The white blood count rose to 25,000. Physical examination at that time revealed a great deal of spasm and tenderness over the upper part of the abdomen, with tenderness and rebound tenderness extending even to the left lower quadrant. Because of the severity of the symptoms, it was decided that immediate operation was necessary in spite of the poor state of the patient's nutrition. The operation was done, using local anesthesia supplemented by gas oxygen and ether inhalation anesthesia.

Operative Findings.—The gall bladder was markedly distended to three times its normal size. The walls of the gall bladder were very thickened and edematous. There was a considerable amount of purulent plastic exudate around the gall bladder, the gastrohepatic omentum, and common duct. There was a great deal of free semipurulent fluid in the peritoneal cavity. The common duct was enlarged to the size of a thumb. The pancreas was greatly inflamed and thickened. This inflammation spread over the head and all of the body of the pancreas. It was approximately 6 cm. in thickness in its anteroposterior diameter.

Operative Procedure.—A right upper quadrant midrectus incision was used. The gall bladder was removed from below upward. It shelled out readily from its bed. The common duct was opened and explored; no stones were found. A T tube was placed in the common duct for continued prolonged biliary drainage. The gall bladder did not contain stones.

Postoperative Convalescence.—The patient had an uneventful postoperative convalescence. Two weeks postoperatively routine pressure studies were made on the bile duct, and cholangiograms were taken. The resting intrabiliary pressure was 0. The pressure following injection of morphine was 50 mm. of water, the perfusion pain pressure was 500 mm. of water. Roentgenographic examination taken at rest showed the duodenum to be in a moderate state of spasm. There was some narrowing of the lower end of the common bile duct and there was some regurgitation of bile into the pancreatic duct (Fig. 1A). Following injection of morphine there was a great deal of duodenal spasm (Fig. 1B). Following inhalation of amyl nitrite, the duodenal spasm was completely relaxed and the media flowed freely from the common duct into the duodenum (Fig. 1C). There was still some regurgitation of bile into the pancreatic duct indicating a small degree of stricture at the ampulla of Vater.

Clamping of the T tube was then begun, beginning with one-half hour twice a day and increasing by one-half hour twice a day. After the tube was clamped off continuously night and day for a period of ten days, the patient developed chills and fever. She also complained of a pain in the right upper quadrant of the abdomen radiating into the right scapular region. The tube was then opened and drainage re-established. These symptoms promptly cleared up. After drainage for another week, the clamping began as before. This time the clamping continued until the tube was completely clamped off for a period of three weeks, and the patient was entirely symptom free. The T tube was then removed. The patient has been symptom free since that time so far as the biliary tract is concerned.

Postoperatively, pus and blood continued to be discharged from the rectum. Proctoscopic examination revealed the presence of ulcerative colitis, moderately severe. Roentgenologic examination of the colon confirmed these findings. She was then given sulfasuxidine for one week followed by sulfathiazole for another week with excellent results. The discharge cleared up. The number of stools were reduced from ten a day to one a day.

DISCUSSION

The chain of events in this case occurred probably as follows: The narrowing of the outlet of the ampulla of Vater resulted in regurgitation of bile from the common bile duct into the pancreatic duct. Pancreatitis developed. The swelling in the head of the pancreas produced obstruction of the common duct, resulting in cholangitis and cholecystitis. When the gall bladder contracted in an attempt to empty the bile into the duodenum, the regurgitation of bile into the pancreatic duct increased. This aggravated the pancreatitis. Cholangitis and cholecystitis were made worse, and so a vicious cycle resulted. One would expect removal of the gall bladder to reduce the potential intraductal pressure to that of the secretion pressure of the liver and so tend to cut down the regurgitation of bile into the pancreas. In such case, therefore, cholecystectomy would be expected to be beneficial in clearing up the pancreatitis.

The patient had periodic attacks of chills and fever. Since she lived in a malaria area, this syndrome constituted a diagnostic problem. It is very probable that several of the alleged attacks of malaria were actually due to cholangitis. Cholangitis should always be considered as a cause of chills and fever. The cholecystectomy in this type of case must be looked upon as only one step in the correction of the physiologicopathologic disturbances present. Continued and prolonged drainage of the common duct must be considered of great importance.

In general, in the postoperative care of patients with diseases of the gall bladder, the use of opiates should be avoided since they produce marked duodenal spasm and back pressure in the common duct. However, in a patient with T-tube drainage, duodenal spasm can do no great harm since there is an escape of bile through the T tube. It has been found that dilaudid is a much more desirable analgesic in these cases since it produces less duodenal spasm. Occasionally even dilaudid produces nausea and vomiting from duodenal spasm. This effect can be neutralized by the addition of nitroglycerin, $\frac{1}{100}$ gr. to each dose given. In using nitroglycerin to relax duodenal spasm, one must be sure to obtain a brand that has a consistent potency. Some of the brands studied, particularly the tablet triturates, were found to be relatively inert. The hypodermic tablets are more consistent in their potency. The nitroglycerin granules are more desirable for sublingual administration.

In the case reported, the spasm was not of a prime factor, since the common bile duct and pancreatic duct entered the duodenal wall through different tunnels. If the pancreatic duct and common bile duct had joined before entering the duodenum, as occurs in some cases, the use of morphine would be very detrimental. In such cases the spasm would produce an obstruction beyond the union of the two ducts and so result in more regurgitation of bile into the pancreas. The roentgenogram shown in Fig. 1B indicates that the duodenal spasm acts separately on the two ducts and that there is no regurgitation into the pancreatic duct in spite of marked duodenal spasm.

Just what relationship the chronic ulcerative colitis had to the pancreatitis and cholangitis is difficult to say. It is very probable that the disturbance of nutrition as a result of malfunction of the pancreas and liver resulted in lower tissue resistance and was a factor, at least, in the persistence of the ulcerative colitis. With this in mind, a great deal of attention was paid to the patient's nutrition. She was given liver extract intramuscularly and was given all the vitamins as well. The reason for giving sulfasuxidine and sulfathiazole alternately is as follows: The sulfasuxidine acts within the bowel lumen, reducing the number of bacteria present. However, it has no beneficial effects at the base of the ulcers or in the lymphatics in the bowel wall. The sulfathiazole takes care of the latter.

SUMMARY

1. A case is presented in which it is believed that stricture of the ampulla of Vater produced a regurgitation of bile into the pancreatic duct and pancreatitis. Pancreatitis then produced obstruction to the common bile duct and gall bladder resulting in cholangitis and cholecystitis.

2. Chills and fever, common symptoms of cholangitis, may be confused with malaria in malaria areas.

3. Removal of the gall bladder is only one step in the right direction in the treatment of chronic pancreatitis and cholangitis. It should be accompanied by T-tube drainage of the common bile duct. The T tube should not be removed until all evidence of pancreatitis and cholangitis have disappeared.

4. Spasm of the duodenum, an important factor in postcholecystectomy syndrome, is of no importance in this particular case since the common bile duct and pancreatic duct enter the duodenal wall through separate tunnels opening into the ampulla of Vater inside the duodenum.

5. The T tube must not be removed too early. It should not be removed until: (a) The resting intrabiliary pressure is 30 mm. or less of water; (b)

the perfusion pain level is 500 mm. or more; (c) roentgenologic studies of the common bile duct show the absence of any obstruction to the flow of bile into the duodenum. Finally, the T tube should be continuously clamped for a period of three weeks with the patient entirely symptom free.

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SPONTANEOUS RUPTURE OF LOWER COLON WITH EVISCERATION OF SMALL INTESTINE THROUGH THE ANAL ORIFICE

A COMPLICATION OF ADVANCED RECTAL PROLAPSE

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THE protrusion of loops of small intestine through the anal orifice is a bizarre sight which has only occasionally been observed. It depends upon certain etiologic factors and pathologic states which are interesting to consider. A survey of the literature reveals only six previously recorded cases. Our case, reported herewith, has stirred us to seek a common explanation for this rare type of evisceration in these several patients. A review of case histories brings to light the fact that in six spontaneous cases, including ours, the patients were known to be previously afflicted with an advanced state of rectal prolapse (proctidentia); the seventh, and remaining case, that of a young girl, was caused by severe crushing trauma without antecedent prolapse. Consequently, it can be stated that rectal prolapse is an etiologic factor of prime importance in the occurrence of this rare type of evisceration. And conversely, one can classify spontaneous rupture of the lower colon and evisceration through the anal orifice as a definite complication, though an unusual one, of advanced rectal prolapse.

CASE REPORT

J. T. A., a 76-year-old unmarried woman, was admitted to the Union Memorial Hospital, the evening of Oct. 15, 1942. Since June, 1933, she had been a patient at the Home for Incurables, afflicted with advanced chronic arthritis. She had been known to suffer from hemorrhoids and had been examined by one of us (S. McL.) several years previously in connection with an extensive rectal prolapse, which had been the cause of considerable distress. However, she was able to be up and about a part of the time and could feed and care for herself. The following description of what took place late in the afternoon of Oct. 15, 1942, was supplied by the nurse who attended her. "In an attempt to get from the commode to the bed, the patient fell to the floor. She was found lying on the floor with what seemed to be the lower intestines hanging from the rectum and a moderate amount of blood surrounding same. I was able to observe peristalsis of the intestines. Intestines were then covered with sterile linen and the patient lifted into bed." The medical director of the Home saw her

immediately and requested surgical help. Fig. 1, drawn from a colored photograph taken at the time, illustrates the general appearance of the evisceration. The patient was transferred at once to the Union Memorial Hospital.

Upon examination, temperature was 98° F., pulse 84 beats per minute, and respiratory rate 20. She looked her age, and was somewhat senile mentally. She did not appear to be in much pain, nor did she present the usual characteristics of shock. There was a marked dorsal kyphosis with ankylosis of the spine and an ankylosis of both hips in a position of 35 degrees of flexion. The heart and lungs presented no gross abnormality. The abdomen was not distended and its walls were moderately well relaxed. The most remarkable finding was the presence of approximately five feet (152 cm.) of small intestine lying between the patient's thighs, the loops having eviscerated by way of the anal orifice. The serosal surfaces were apparent. The color was good and normal peristalsis was taking place. There was no protruding rectal mucous membrane. Examination of the anal canal showed the sphincter to be very relaxed. The afferent and efferent loops were definitely traversing the anal canal and the site of their egress from the peritoneal cavity could not be determined.

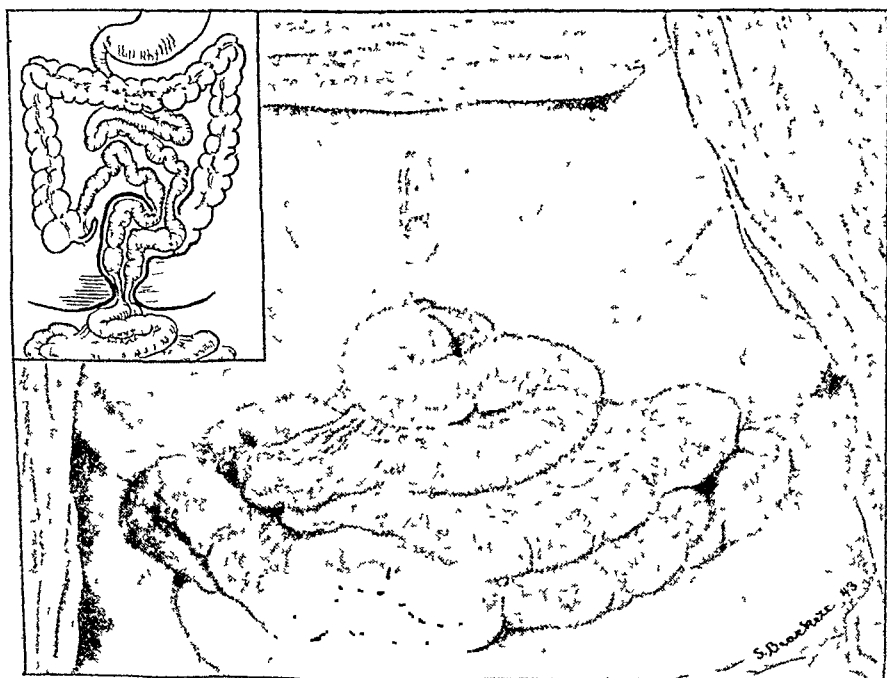


Fig. 1.—Drawing taken from colored photograph showing evisceration of small intestine through anal orifice following rupture of the lower sigmoid in a case of recurrent rectal procidentia.

A future attempt was made to manipulate gently the intestinal coils in order to replace them. Laparotomy was decided upon and under ether anesthesia a low midline incision was made (M. L. J.). When the peritoneal cavity was opened, the explanation of the trouble was at once apparent. There was a rent in the anterior wall of the sigmoid colon, about six inches (15 cm.) above the peritoneal reflection on the rectum. This rent was about 2½ inches (6 cm.) long and did not appear to represent a pathologic area in the colon. Through it was protruding a large part of the small intestine, much of which in turn passed through the anal orifice to the exterior. The intestine was quickly drawn back into the peritoneal cavity, care being taken to sponge off any visible foreign particles. It was found that the loop of sigmoid which had been torn would reach to the anterior abdominal wall and consequently it was brought out through a left muscle splitting incision as a colostomy. This was done with the idea of avoiding a repetition of the accident which had just occurred. Crystalline sulfanilamide in the amount of 7 Gm. was placed in the peritoneal cavity, 3 Gm. being used for the wound margins. The wound was quickly closed with buried chromic catgut and silk in the skin, and the patient left the operating room in fair condition.

There was no significant elevation of temperature or pulse during the postoperative period, nor was there vomiting or distention. On the day following operation, the leucocytes

numbered 6,600 and the hemoglobin was 76 per cent. Despite intramuscular administration of prostigmine and pitressin, no bowel movement occurred. Quietly but quickly she died, about sixty-two hours after operation.

Post-mortem examination disclosed a widespread confluent pneumonia, and on the right side an esophagopulmonary fistula, the walls of which showed evidences of acute inflammation. Within the abdomen there were many fresh adhesions and several small abscesses, indicating peritonitis. The stomach and duodenum were moderately distended. There was marked arteriosclerosis.

The following are abstracts of six previously reported cases.

CASE 1 (Moulton¹).—The patient was an insane man who had acquired the ability to produce rectal prolapse and inversion at will. One day the attendant discovered him with a loop of small intestine two feet in length hanging with its mesentery from the rectum. There was a tear in the wall of the rectum through which the small intestine protruded. The patient was said to have died in thirty-six hours "from shock." There was no operation.

CASE 2 (Guibe²).—A 78-year-old woman gave a long history of rectal prolapse. Having an imperative desire to go to stool one day and making a violent effort, she experienced a sharp pain and a mass of small intestine escaped through the anal orifice. The following morning, a laparotomy was performed under local anesthesia, and it was necessary to resect 130 cm. of gangrenous, protruding bowel. There was a tear, 3 cm. in length through the anterior band of the sigmoid, about 10 cm. above the cul-de-sac. This was closed. Eight days later, a fecal fistula developed. After six weeks she left the hospital with a small fistula, but became cachectic and died one month later.

CASE 3 (Guide²).—A 77-year-old woman with a history of prolapse of the rectum fell down the stairs, sustaining a painful contusion in the region of the coccyx and experiencing a sensation of something breaking. Upon examination it was ascertained that 1.5 meters of small intestine and 30 cm. of sigmoid and descending colon were protruding from the anus. The rupture was situated at the intraperitoneal part of the rectum about 3 cm. above the base of the cul-de-sac. The rent was 9 cm. long and the bowel was otherwise in good condition. The rectum was sutured, peritoneal cavity irrigated, and sigmoidostomy performed. She died on the fifth day with signs of peritonitis. Autopsy showed that "the loops of intestine for a distance of 2 meters terminating at the ileocecal valve were dark red and there were many suffusions of blood in the intestine and mesentery."

CASE 4 (Moskalenko³).—This patient was a 52-year-old woman with a fifteen-year history of rectal prolapse. On the morning of admission she had defecated, apparently out in the fields, when seized with a sudden severe cough. She experienced an immediate, sharp abdominal pain during which her intestines were extruded through the rectum. When first seen, the intestines were cyanotic and covered with earth and straw. Her general condition was fair. Laparotomy was performed fifteen hours after the accident. Fecal soiling of the peritoneum was present. About one-half of the small bowel had prolapsed outside and resection of this amount was necessary. The tear in the rectum, 8 cm. in length on the anterior surface near the bottom of the pouch of Douglas, was sutured. The patient died in twenty-four hours of heart failure. At autopsy attention was directed chiefly to the cul-de-sac of Douglas. It was found that this pouch was much deeper and fuller than normal and that when pressure was applied, only a thin layer of bowel wall intervened to prevent extrusion of the abdominal viscera.

CASE 5 (Erlikhmana⁴).—A 45-year-old laundress with a history of rectal prolapse was stricken with a severe pain in the lower abdomen while carrying a heavy load of wet laundry. There was an evisceration through the rectum of almost the entire small intestine. Laparotomy was performed under ether-chloroform anesthesia; the intestines were pulled back into the peritoneal cavity and washed with normal salt solution. The rectal wound, which was on the anterior wall of the pelvic portion of the rectum, was sutured in two layers. The patient died in sixty-four hours with generalized peritonitis. Examination of the ruptured area of the rectum revealed an ulcer measuring approximately 9 by 1.5 cm., running transversely to the long axis of the gut. The microscopic examination of the ulcerated portion of the rectum revealed an ordinary scarred ulcer having no specific characteristics.

CASE 6 (Zena, D.⁵).—(This was not a spontaneous rupture but one which resulted from external violence.) A 12-year-old girl suffered multiple injuries when caught in a cave-in. Approximately 80 cm. of small intestine were found to protrude from the anus. At laparotomy,

the intestine was replaced and the injured area of the rectum excised and sutured. A drain was introduced. The patient was out of danger in two days. Anal incontinence and some diarrhea were present for a short time, but complete recovery eventually occurred.

DISCUSSION

Manifestly, in an otherwise normal individual, the complication to be expected to accompany a rupture or laceration of the intestine is the free passage of intestinal contents into the peritoneal cavity. In this less common type of rupture of the intestine, the prime complication is the passage of peritoneal cavity contents into the lumen of the bowel and, indeed, on to the outside. Both Lynch⁶ and Bacon⁷ in their textbooks have mentioned rupture of the protruding rectal wall with evisceration as a serious but infrequent occurrence in rectal prolapse. The pathologic anatomy which permits intra-abdominal forces to tear the lower intestine in this fashion is, of course, the root of the trouble.

In advanced rectal prolapse or in procidentia, a single thickness of the wall of the upper rectum or sigmoid is called upon to assume all of the intra-abdominal stress without the aid of the normally supporting structures. Among these structures are the intact pelvic floor and the competent anal sphincter. In women, the area of rectal wall subject to the greatest stress is that which lies anteriorly in Douglas' cul-de-sac. The very fact that its serosa is reflected anteriorly and finally becomes fixed contributes in no small measure to the susceptibility of this bowel segment when the proper forces are in effect. With the rectum in a prolapsed position and with the hernia-like pouch formed by the anterior wall of the rectum and sigmoid filled with small intestine, it is not difficult to appreciate how rupture and sudden evisceration may occur.

Wangensteen⁸ quotes the work of Hay (1940) in determining the breaking strength of the human bowel removed at operation. In a series of ten patients the bursting strength was noted to vary between 80 and 260 mm. of mercury, truly a wide range. This type of experiment, however, represents a different approach to the problem as it deals with intraluminal pressures and is not entirely applicable to external (intraperitoneal) pressures and stresses.

There is little to advance or suggest with regard to treatment. The patients must be managed according to accepted principles for abdominal trauma, which will necessarily mean laparotomy with repair of the defect. Resection has been carried out several times. It is a situation requiring judgment and initiative adapted to each case. The results in the reported cases have been poor. Of the six spontaneous ruptures, five were operated upon and only one patient survived for one month. The young girl who had a traumatic rupture with evisceration unaccompanied by an antecedent prolapse recovered. It is true that advanced age and unfavorable physical condition often accompanied the immediate catastrophe. Consequently, it may be concluded, as in other types of large intestinal wounds and perforations, that the prognosis is not good. This very fact of poor prognosis, however, presents an added reason for the early surgical correction of rectal prolapse before it reaches an advanced and complicated state.

CONCLUSIONS

1. A case of spontaneous evisceration of small intestine through the anal orifice following a rupture of the sigmoid colon is reported.

2. A review of six previously reported similar cases reveals the interesting fact that in five of these as well as in our own, the patients had had a pre-existing rectal prolapse.

3. This observation leads to the conclusion that rectal prolapse (procidentia) is an etiologic situation of prime importance in the occurrence of this rare type of evisceration.

4. The pathologic anatomy permits the requisite force to be directed against the anterior wall of the rectum or colon in a manner to cause rupture when procidentia exists and when that wall is no longer supported by the intact pelvic floor and the competent anal sphincter.

5. The poor prognosis in this late complication presents an added reason for the early correction of rectal prolapse.

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THREE HUNDRED FIFTY-TWO CASES OF TETANUS

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THERE were 352 patients with tetanus treated in the Charity Hospital of Louisiana at New Orleans during the ten-year period of Nov. 1, 1934, to Oct. 31, 1944. The total mortality was 45 per cent. There has been previously published in the medical literature four articles which together with this one, review the treatment given all patients with tetanus treated at Charity Hospital during the years of 1906 to 1944. In 1935, Boyce and McFetridge¹ reported 185 cases, with a mortality of 59.5 per cent for the period from Jan. 1, 1930, to Oct. 31, 1934. In 1930, Graves² reported 217 cases, with a mortality of 52 per cent for the period from 1923 through 1929. In 1916, Gessner and Adiger³ reported 368 cases covering the period from 1906, with a mortality of approximately 70 per cent, and in 1924, Graffagnino and Davidson⁴ brought this number of cases to 596, with a mortality for the combined series of 67.4 per cent.

Vener and Bower,⁵ in 1941, reported 100 cases during an unstated period from the Los Angeles County General Hospital, with a mortality of 29 per cent. They, together with McKillop,⁶ had reported, in 1933, a series of 131 cases, with a mortality of 50 per cent. Moore and Singleton,⁷ in 1939, reported 102 cases from 1906 to 1939 at the John Sealy Hospital in Galveston, Texas, with a mortality of 50 per cent. Kirtley⁸ of Nashville, Tenn., reported 60 cases from 1925 to 1938, with a mortality of 46.6 per cent. In 1940, Dietrich⁹ reported 28 cases from the Children's Hospital in Hollywood, Calif., with a mor-

tality of 47 per cent. He emphasized the fact that from 1921 to 1932, 12 of 15 of these children died, while from 1932 to 1939 only 1 of 13 children died. He attributed most, if not all, of these deaths to faulty methods of administration and to too large doses of the tetanus antiserum.

The yearly distribution and mortality of this series are shown in Table I.

TABLE I

NUMBER OF CASES	YEAR	NUMBER OF DEATHS	PER CENT
5	Nov. & Dec., 1934	3	60
41	1935	21	51
32	1936	20	51
33	1937	13	40
41	1938	24	58
24	1939	11	46
43	1940	21	49
42	1941	17	40
26	1942	8	30
31	1943	11	35
34	1st 10 mo., 1944	9	26
Total 352		158	45

One of the main purposes of this article is to emphasize the markedly lowered mortality of 31 per cent among the 91 consecutive cases of the last three years and to outline the therapeutic program which, it is believed, will further lower the tetanus mortality rate.

The monthly distribution and mortality are given in Table II. It is interesting to note that in general the summer months show a higher incidence of the disease but have a much lower mortality.

TABLE II

MONTH	NUMBER OF CASES	DEATHS	PER CENT
Jan.	21	14	67
Feb.	14	7	50
March	27	16	59
April	33	20	61
May	42	14	33
June	39	12	31
July	33	11	33
Aug.	27	11	41
Sept.	46	16	35
Oct.	36	19	53
Nov.	19	10	53
Dec.	15	8	53

The ratio and comparative mortality of age, race, and sex are listed in Table III.

Vener and Bower⁵ reported a mortality in their series of 52 per cent among 25 females and a mortality of 21.3 per cent among 75 males. It is ap-

TABLE III

RACE, SEX, AGE	NUMBER OF CASES	DEATHS	PER CENT
Negro	217	103	47
White	135	55	41
Male	229	106	46
Female	123	52	42
Adults (over 12 yr.)	189	91	48
Children	163	67	41

parent from this tabulation that no such higher female mortality existed in this series, which in fact shows a surprisingly uniform rate of mortality for age, race, and sex.

DIAGNOSIS

In the diagnosis of tetanus the familiar pattern of recent injury, trismus, dysphagia, stiff neck, generalized rigidity, and convulsions probably provides at least as consistent a symptomatology as does any communicable disease. Needless to say, there are variations and atypical clinical pictures. It is certain, however, that if tetanus were seriously considered in the differential diagnosis of any patient presenting two or more of these symptoms, very few cases of tetanus would be misdiagnosed.

In this series there were 26 cases which apparently presented certain definite symptoms or signs of tetanus, but which were unrecognized by the physician at the time of the first examination. Twenty-two of these patients were seen in the emergency or admitting rooms of Charity Hospital by interns or residents, and 4 were seen by private physicians.

Of the 4 patients who were seen by private physicians, 1 who had complaints of trismus and generalized rigidity was diagnosed as having worms and sent home; 1 patient who was having convulsions had no diagnosis and was sent home, as were the other 2 patients who had speech impairment, trismus, and some muscular rigidity.

Eight of the patients who were seen at Charity Hospital were sent home; 3 of them gave a history of having convulsions, and the other 5 had two or more of the symptoms of trismus, stiff neck, muscular rigidity, or contractions.

Certainly the criticism, if any, of the handling of these cases should be directed not toward the failure in diagnosing them correctly, but rather the failure to hospitalize and study any patient presenting such symptoms. Dietrich⁹ stated that of the 28 cases in children reported in 1940, only 17 were diagnosed as tetanus at the time of hospital admission.

Fourteen patients were admitted to the hospital and treated for variable lengths of time (one to seven days) under various diagnoses before the diagnosis of tetanus was made and antitetanus treatment instituted. The tentative diagnoses on these patients were as follows: deferred, 3; hysteria, 3; meningitis, 3; carcinoma of esophagus, 1; chronic otitis media and mastoiditis, 1; pneumonia, 1; cellulitis of face, 1; undiagnosed autopsy, 1. The mortality for this group of patients was 14 deaths, or 56 per cent. There were also 2 cases tentatively diagnosed as tetanus until they came to autopsy. One of these patients was found to have a generalized peritonitis and toxemia from a traumatic perforation of the right colon. The other had pulmonary tuberculosis and a brain tumor.

PROPHYLAXIS

It is estimated that an average of 65 patients daily has received antitetanus serum at Charity Hospital for the last ten years. This would give a total of 237,250 patients receiving the serum during this period of time.

Ten patients who had received a prophylactic dose of antitetanus serum at the Charity Hospital emergency rooms within twenty-four hours of the injury, later developed tetanus. Six of these patients died, a mortality of 60 per cent. Nine of these patients had received 1,500 units of antitetanus serum. The remaining patient received a double dose of mixed antitetanus and gas gangrene serum.

Assuming that all patients who received antitetanus serum at Charity Hospital return there for treatment should tetanus develop, we find a mortality

for tetanus of 24 per million of those who receive the prophylactic antitoxin. This compares favorably with the records of the Bureau of Vital Statistics, which give an annual mortality in the state of Louisiana of about 40 per million of population.

The records of the Bureau of Vital Statistics¹⁰ reveal that tetanus is most prevalent in the states immediately surrounding the Gulf of Mexico. The incidence steadily diminishes as one progresses northward. It is rare in the far northeastern states and in the states west of the western borders of Texas, Kansas, Nebraska, and Minnesota, except for a moderate incidence in Arizona and California.

The list of injuries from which tetanus has developed in this series includes many insignificant scratches, minor abrasions, or minute puncture wounds. When one considers how many of such types of injuries are received each year by the average person it is clearly illogical to expect or to suggest that antitetanus serum be given for each such injury. However, from studying the types of wounds from which most of these cases of tetanus have developed, there emerge certain very definite indications in the tetanus-prevalent areas for débridement and prophylactic antiserum. Lay people should be educated to recognize these indications and to seek medical care for each such type of injury. Foremost among these are puncture wounds, second are splinters, and third are all secondarily infected and suppurating wounds. To these may well be added burns, subdermal lacerations, and infected surgical incisions. It should also be remembered that the duration of the passive immunity produced by the antitoxin is not more than eight or ten days, and should therefore be repeated at such intervals for wounds that remain open or chronically infected for longer periods of time. It is also believed that especially in the more tetanus-prevalent areas no physician can safely treat any traumatic lesion, however insignificant, without also administering antitetanus serum.

For minor traumatic lesions which will not receive a physician's care, probably the next best insurance against tetanus is an immediate thorough scrubbing of the wound with soap and water. This treatment is, of course, entirely ineffective in conditions previously described in which débridement and antitoxin are definitely indicated.

It is hoped that the time will come soon when routine immunization by tetanus toxoid among the population of tetanus-prevalent areas will be done. Certainly the efficacy of such a procedure has been proved by the experience of the Armed Services in World War II, and at present appears to be the only known solution to the prevention of the disease. The United States Army method of toxoid administration¹¹ is to give three injections of 1 c.c. each at monthly intervals, followed by a booster dose of 1 c.c. at the end of twelve months, and thereafter an additional 1 c.c. in the event of an injury, providing more than six months have elapsed since the previous injection.

CLASSIFICATION OF CASES

For a more detailed study the cases have been classified according to origin of infection as follows: tetanus neonatorum, gynecologic, surgical, chronic skin lesions, unknown, and traumatic. These will be considered separately.

Tetanus Neonatorum (11 Cases).—There were 11 patients with tetanus neonatorum in the series, all of whom showed evidence of umbilical cord infection. Six of these patients died, a mortality of 55 per cent. One of these patients died on the first hospital day, 2 died on the second, 2 on the third, and 1 on the ninth hospital day. Of the 5 who recovered, their period of hospitalization varied

from twenty-one to forty-five days, an average of thirty-three days. The age of the patient at the time of onset of symptoms varied from 8 to 12 days.

Three were unattended deliveries, 2 at home where no dressing was placed over the umbilicus of 1, and 1 was born in an automobile; 2 others were also home deliveries, 1 attended by a private physician and 1 attended by a medical student. The circumstances of birth of the other 6 are not recorded. All these patients were hospitalized and antitetanus treatment instituted within from two to four days of onset of symptoms. Six of them received 20,000 to 25,000 units of antitetanus serum intramuscularly on admission. Three of these died on or before the third day and the other three recovered. One patient received 20,000 units intravenously on admission, but received no subsequent doses and died on the third day. One patient received 60,000 units intravenously and 20,000 units intramuscularly on admission, with no subsequent doses, and died on the ninth day. Three patients received 40,000 or 50,000 units intramuscularly on admission, 2 of whom recovered, and the other 1 died on the third day. Eight of the 11 patients received no débridement, of whom 5 died. Umbilectomy was done on 3 patients of whom 1 died.

It would seem well at this point to re-emphasize the fundamental principle of giving antitoxin to children, namely that the antitoxin is to be given in sufficient quantities to neutralize the toxin. A focus of infection will produce as much toxin in an infant as it will in an adult. Hence, no reduction in the amount of antitoxin for a child or infant, however small, is permissible. The inescapable conclusion is that the mortality for this particular group of patients could have been appreciably reduced by routine umbilectomy and initial doses of 80 to 100,000 units of antiserum by the intramuscular and intravenous routes.

Surgical (11 Cases).—Eleven of the cases followed a surgical procedure. Six of these patients died, a mortality of 55 per cent. The periods of incubation varied from two to twenty days, an average of nine days. Five of these cases followed extraction of teeth, from which 3 patients died. One case followed a combined appendectomy and tonsillectomy, 1 a hernioplasty with resection of bowel, 1 a hysterectomy, 1 a ganglionectomy, and 1 an excision of a cheek lesion. The incisions of all these patients showed evidence of gross infection from one to four days before the signs of tetanus developed. The remaining case followed a hypodermic injection by a private physician to a school child.

Chronic Skin Lesions (9 Cases).—There were 9 cases where the site of infection was thought to be in chronic skin lesions which had been present for at least several months. Six of these patients died, a mortality of 67 per cent. Four of these patients had chronic leg ulcers, 1 had an infected skin rash, 1 a chronic sore on the penis, 1 multiple decubitus ulcers, 1 a chronic draining osteomyelitis, and 1 an infected draining ear.

Gynecologic (14 Cases).—There were 14 patients with gynecologic tetanus, 6 of whom died, a mortality of 43 per cent. Twelve of these followed abortions, 8 of which were induced by midwife manipulations, 1 was self-induced with a catheter, and 3 were recorded as of unknown cause. One case developed following an uncomplicated hospital delivery, and the remaining patient developed tetanus following an induced labor on an eclamptic by means of a Voorhees bag.

Unknown (38 Cases).—In 38 of the cases no history of any injury could be elicited and no possible site of infection found. Twelve of these patients died, a mortality of 32 per cent.

TABLE IV

LOCATION	NUMBER OF CASES	AVERAGE INCUBATION PERIOD (DAYS)	DEATHS	PER CENT
Lower extremity	205	12.6	91	44
Upper extremity	42	10.2	24	57
Head	17	8.6	9	53
Trunk	2	10.5	0	--
Multiple	3	---	1	33

Traumatic (269 Cases).—Two hundred sixty-nine cases in the series gave a definite history of recent injury or presented a traumatic site of infection. The incubation period varied from 1 to 100 days, an average of twelve days. The anatomic distribution was as shown in Table IV.

The distribution of the types of wounds is listed in Table V.

TABLE V

WOUND	NUMBER OF CASES	AVERAGE INCUBATION PERIOD (DAYS)	DEATHS	PER CENT
Puncture	101	12.7	50	50
Splinter	69	10.2	30	43
Laceration	54	11.9	26	46
Scratch	11	7.2	5	45
Abrasion	16	9.0	6	38
Burn	3	20.0	1	33
Bite (1 dog, 1 rat)	2	30.0	1	50
Compound fracture	3	11.7	3	100
Crushing	3	14.7	1	33
Amputation of finger	2	10.0	0	--
Multiple	4	---	1	25
Abscess	1	5.0	0	--

Of the 101 puncture wounds, 71 were from nails, 7 unknown, 5 tacks, 5 bone, 3 pins, 2 wires, 2 pitchforks, 2 rakes, 1 ice pick, 1 needle, 1 shoe nail, 1 steel tong. Of the 69 splinters, 58 were wood, 3 thorns, 2 steel, 1 soybean barb, 1 weed, 1 bone, 2 shells, and 1 unknown. Of 54 lacerations, 18 were caused by unknown objects, 16 by glass, 4 brick, 3 tin, 2 shell, 2 cement walks, 2 knives, and 7 miscellaneous. The ages of the patients in this group ranged from a few months to 74 years. It is very evident that no age or class of people is immune and that no injury is too trivial to cause tetanus.

In an attempt to evaluate the relationship between the length of the incubation period and the mortality rate, 253 patients were selected who gave a definite history of injury with a known incubation period (see Table VI).

TABLE VI

INCUBATION PERIOD (DAYS)	NUMBER OF PATIENTS	DEATHS	PER CENT
1-5	43	19	44
6-10	97	60	62
11-15	60	22	37
16-20	24	7	29
20-50	26	7	27
51-100	3	0	--

These statistics agree with the generally accepted view that longer incubation periods are associated with lower mortality rates. The presence of a lesser mortality rate among the patients in the one- to five-day incubation

period group than in the six- to ten-day group is in decided contrast to most other published series of cases. However, it should be remembered that all cases with a history of a very short or a very long incubation period should be regarded with some doubt, as the true cause of infection may have occurred unnoticed or forgotten at some other time.

TREATMENT

The experimental work of Firor¹² indicates that the tetanus toxin is carried from the focus of infection by the lymphatics and blood vessels. In the tissue of the central nervous system the toxin is altered by some unknown irreversible process to form a new toxic substance which circulates in the blood and which is not neutralized or affected by tetanus antitoxin, and which in sufficiently large quantities produces death. It follows then that once a lethal amount of toxin has been fixed by the central nervous system, no amount of tetanus antitoxin or other therapy will alter or affect the fatal termination of the disease. Since it is impossible to tell in any given case when a fatal amount of antitoxin-resistant toxin has been produced, this knowledge should in no way influence the treatment of any patient. It must be remembered that very severe symptoms and convulsions may result from less than a fatal amount of toxin.

If one accepts this concept of a constant progressive building up toward a fatal amount of antitoxin-resistant toxin, the importance of immediate administration of sufficient amounts of antitoxin by the most effective route becomes clearly apparent. At any hour or even minute the fatal amount of antitoxin-resistant toxin may be accumulated and the disease at that moment progresses from a curable to an incurable one.

For the initial treatment then in any case tentatively diagnosed as tetanus, the following steps are suggested in the order given. First, determine that the patient is not sensitive to the antiserum by a skin test. This can be read in fifteen minutes, during which time the antiserum can be prepared and the patient sedated if necessary. If the skin test is negative, 50,000 to 60,000 units of antiserum diluted in about 300 c.c. of normal saline solution should be started intravenously immediately and allowed to be absorbed in thirty to forty minutes. An equal amount may be administered intramuscularly at the same time. Should the skin test be positive, desensitization by the standard procedure must be carried out and usually two or more hours must elapse before intravenous administration of antiserum can be begun. This delay is regrettable, but unavoidable in the case of serum-sensitive patients.

Obviously no form of treatment is complete without a complete excision and eradication of the primary site of infection where the toxin is being constantly produced. This then should be the next step in the initial treatment. Under local or general anesthesia, as indicated, a complete and radical débridement or excision must be done whenever possible. In cases where multiple possible foci of infection exist or where no history of trauma is obtainable, the entire surface of the body should be inspected and all possible foci of infection excised or débrided. The further local treatment of these excised areas is probably adequately cared for by applications of some oxidizing substance such as hydrogen peroxide or zinc peroxide.

Firor¹² recommended an initial dose of 50,000 units of antiserum intravenously, 10,000 to 20,000 units locally around the site of infection prior to débridement, and 20,000 units intraspinally. He followed this by giving 5,000 units intramuscularly daily for eight to ten days.

At Charity Hospital during the last three or four years most of the tetanus patients have received 40,000 to 60,000 units of antiserum intravenously and an equal amount intramuscularly on admission. The subsequent administration has varied from repeating a similar dose on the second day with none thereafter to giving from 10,000 to 40,000 units daily for eight to ten days. It should be remembered that in cases where the foci of infection cannot be found or removed, much larger doses of the antitetanus serum should be continued daily for a longer period of time. Prior to about 1939, much smaller amounts of antiserum were customarily administered. Only 2 patients in the series received the antiserum intraspinally, both of whom lived, and only 11 patients received a local infiltration of antiserum around the wound site, of whom 4 died. Several authors have presented evidence that intraspinal administration of antiserum is not only without therapeutic value, but is probably harmful. Firor,¹² Jensen,¹³ Caviness,¹⁴ Weinstein and Beacham,¹⁵ and Vener and Bowen⁶ have advocated the use of intraspinal administration and Aud,¹⁶ Kirtley,⁸ Dietrich,⁹ and Boyce and McPettridge¹ have emphasized the high incidence of severe, and in many cases fatal, reactions, especially in children, following such intrathecal administration. It is rather difficult to conceive of the efficacy of intrathecal administration in view of the now quite conclusive evidence that tetanus toxin once fixed in the tissue of the central nervous system is no longer neutralized by antitoxin.

The importance of good nursing care of these patients cannot be over-emphasized. The mortality of severe tetanus cases will not be appreciably decreased until each of these patients can be under constant supervision by a specially trained and experienced nurse.

In the further treatment of the patient there has been no routine procedure or set of orders. The following orders are presented as being fairly representative of the care that most of these patients received subsequent to the initial treatment:

1. Weigh patient
2. Chart intake and output
3. Keep gastric tube in stomach continuously
4. Provide special tube feedings every four hours
5. Give 3,000 to 4,000 c.c. of fluids daily
6. Turn patient frequently
7. Keep room darkened and quiet
8. Have only one attendant in the room at one time
9. Provide continuous nasal oxygen
10. Aspirate mouth and pharynx whenever necessary
11. Give ephedrine sulfate 1 per cent nose drops every three to four hours
12. Administer atropine, gr. $\frac{1}{150}$, every six to eight hours
13. Provide sulfadiazine, 1.0 Gm., every four hours
14. Give sodium bicarbonate, 2.0 Gm., every four hours
15. Use Trendelenburg position
16. Furnish avertin, 70 to 90 mg. per kilogram of body weight rectally every six hours for restlessness
17. Administer phenobarbital, gr. 2, every four hours as necessary to keep patient well sedated
18. Give sodium amytal, gr. $7\frac{1}{2}$, intravenously as necessary for control of convulsions

The rationale of most of these orders is apparent. Atropine is given to aid in producing muscular relaxation as well as to decrease the respiratory tract secretions in a heavily sedated patient. The high caloric and high vitamin tube feedings are vitally important in the care of these patients. A patient who is having generalized muscular contractions is undoubtedly burning up a great deal of energy and must be provided with an intake of at least 3,000 to 4,000 calories daily. The administration of sulfonamides in therapeutic doses has become practically routine since 1941. This has been concomitant with a markedly decreased mortality rate. It is believed that the sulfonamides have an important role in lessening the mortality rate by helping to eliminate bronchopneumonia as a complicating cause of death. Of the 158 deaths in this series, 32 were recorded as being complicated by bronchopneumonia. It is highly significant that only 2 of these patients received any sulfonamide therapy and each of these 2 received the drug for less than thirty-six hours before death.

It is believed that the four important factors in decreasing the mortality rate are (1) early adequate amounts of antitoxin, (2) complete débridement of the focus of infection, (3) adequate sedation, and (4) sulfonamide therapy. As far as could be ascertained from studying the charts, nearly all these patients received fairly adequate sedation, attained principally by the use of avertin rectally and barbiturates orally, via stomach tube or parenterally. There was, however, considerable variation in the administration of the other three lifesaving measures. A detailed study of the effect of the administration or omission of these three measures on the mortality rate is presented.

Of the 158 deaths in the series, 59 occurred on or before the second day. As far as could be ascertained from these charts, the great majority of these deaths occurred within twenty-four hours of beginning of treatment plus the addition of a few others who died within thirty-six hours. It is believed that these patients may properly be considered as being moribund upon admission and that none of the known methods of treatment, however used, could have saved their lives. Not included in this group is 1 patient who died on the second day following an intravenous injection of curare. This leaves 158 minus 59, or 99 patients to whom the term of preventable or net mortality is applied in contradistinction to the previously mentioned moribund group.

An interesting observation concerning this moribund group is that only 63 per cent were Negroes, which is the same percentage as is the number of Negroes to the total group. This indicates that at least in this series, contrary to generally prevalent opinions, the Negroes did present themselves for treatment in approximately the same stages of the disease as did the white patients.

This leaves 293 patients who were not moribund upon admission, of whom 99 patients died, a net mortality of 34 per cent. Along with other therapeutic measures, 184 of these patients received débridement of the foci of infection, 65 of whom died, a mortality of 36 per cent. Seventy received sulfonamide therapy, of whom 22 died, a mortality of 31 per cent. One hundred twenty-nine patients received an initial dose of antiserum of 40,000 or more units intravenously and 20,000 or more units intramuscularly. Forty-two of these patients died, a mortality of 32 per cent. Of this latter number there were 46 patients who received a higher initial dose of antiserum amounting to 60,000 or more units intravenously and 40,000 or more units intramuscularly. Sixteen of these patients died, a mortality of 29 per cent. A still smaller number of 17 of these patients received 80,000 or more units intravenously, with 40,000 or more intramuscularly. Of this number 7 died, a mortality of 41 per cent.

There were only 39 patients in the series who received sulfonamides, débridement, and the minimal 80,000 or more units of antiserum on admission. Ten of these patients died, a mortality of 26 per cent. Of this latter group there were 20 patients who received the larger initial doses of antiserum, namely, 60,000 or more units intravenously and 40,000 or more units intramuscularly. Seven of these patients died, a mortality of 32 per cent. An even smaller number of this group of patients received an initial dose of 80,000 units or more intravenously and 40,000 or more units intramuscularly. Three of this number died, a mortality of 37 per cent.

These statistics, while not conclusive, indicate that there is a maximum effective initial dose of antiserum which is around 80,000 to 100,000 units, at least one-half of which should be given intravenously. Larger initial doses do not appear to have any appreciable effect on lowering the mortality rate, in fact, are associated with an increased mortality rate.

During the years of 1935 to 1940 there was a constant trend toward increasing the initial dosages of antitetanus serum in the treatment of tetanus. The patients in the series treated by Vener and Bower⁶ and reported in 1941 received 200,000 units of antiserum locally, intramuscularly, intravenously, and intrathecally during the first twenty-four hours of treatment. The fact that they reported the lowest mortality of any large series cannot be overlooked. The excellent general care and nursing facilities accorded those patients, however, should be regarded as another factor in lowering the mortality rate. Caviness,¹⁴ in 1943, recommended total doses as high as 300,000 to 550,000 units and many patients in this present series received as high total dosages. However, Firor¹² has shown quite conclusively that 50,000 units of the antitetanus serum intravenously will neutralize as much toxin as can be present in the blood stream. It would seem then that larger doses and subsequent intramuscular doses are indicated only as a safeguard against possible further production of toxin due to an incomplete or an impossible eradication of the foci of infection.

The total amounts of antiserum given are purposely omitted. Since the subsequent amounts given vary so widely according to the severity of the disease and the intervention of death in the fatal cases, it is believed that the initial doses are the only accurate criteria for a comparison of the therapeutic results.

Treatment of Nine Patients With Curare.—Some discussion has been carried on in recent years regarding the therapeutic value of curare in the treatment of tetanus. Under the supervision of Dr. John Adriani,¹⁷ Director of the Department of Anesthesia at Charity Hospital, 9 patients in this series received intocostarin in an attempt to relax severe muscular spasms. The conclusions, in brief, were that curare has no effect on the course of the disease other than to relax muscle spasms temporarily, for one hour or less, and that use of the drug is accompanied by more hazards and toxic reactions than are justified in view of the temporary and purely symptomatic relief obtained.

Treatment of Five Patients With Penicillin.—Five of these patients received penicillin varying in total amounts from 250,000 to 600,000 units. Two of the patients died, a mortality of 40 per cent, both deaths occurring on the ninth hospital day. No beneficial effect of the drug on the course of the disease other than as a prophylaxis against secondary infection and pneumonia was observed in this small series of 5 cases.

SUMMARY

Three hundred fifty-two patients with tetanus were treated from Nov. 1, 1934, to Oct. 31, 1944.

The total mortality was 45 per cent. Excluding the deaths which occurred in the first thirty-six hours, the net mortality was 34 per cent.

The mortality has been substantially reduced in the last three years, during which time there has been a total mortality of 31 per cent, and a net mortality of 18 per cent.

Further reductions in the mortality rate may be obtained by adherence to the following reiterated factors of treatment:

1. Routine immunizations by tetanus toxoid
2. Routine administration of prophylactic antiserum (preferably 3000 or more units) in the treatment of all injuries to patients who have not previously received toxoid immunization
3. Education of lay people to report early and of doctors to recognize and institute immediate therapy for symptoms of early tetanus
4. Immediate intravenous administration of adequate amounts of antiserum
5. Complete excision or débridement of all possible foci of infection including umbilectomy in cases of tetanus neonatorum
6. Adequate sedation
7. Therapeutic doses of sulfonamides to prevent secondary infection and as prophylaxis against pneumonia
8. Daily administration of 40,000 to 50,000 units of antiserum intramuscularly to all patients in whom the original foci of infection cannot be found or completely removed
9. Good general nursing care
10. Adequate caloric and fluid intake by stomach tube feedings.

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GUNSHOT FRACTURES OF THE SHAFT OF THE HUMERUS

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DURING the North Burma campaign of 1943 and 1944, complete gunshot fractures of the shaft of the humerus comprised approximately 3 per cent of all battle casualties admitted to this general hospital. In comparison with gunshot fractures of other long bones, fractures of the humeral shaft were relatively simple to treat as far as the bone injury was concerned. The hanging plaster, introduced by Caldwell¹ in 1933 and widely used in civilian practice, proved to be ideal for the treatment of the majority of these fractures under conditions of warfare. Bone union in satisfactory position was obtained in almost every instance in which there was no significant bone loss. In spite of this, the high incidence of associated nerve injuries, the less frequent circulatory damage, and nonunion resulting from bone loss made this lesion an important military problem from the standpoint of rehabilitating the soldier and returning him to active duty. By expert treatment of these associated injuries, permanent disability may often be prevented.

ANALYSIS OF CASES

During the campaign, 100 patients with complete gunshot fractures of the humeral shaft were admitted to this hospital. Sixty of these were treated on the orthopedic section and were followed for a sufficiently long period to determine the final result of fracture treatment. These were consecutive cases and were unselected. Because of the exigency of the situation at various periods, the remaining forty patients were treated on the general surgical section. Since these were handled in a somewhat different manner, and because many were dispositioned to other hospitals before the final result was known, they are not included in this analysis.

Thirty-eight per cent of the fractures were in American and 62 per cent in Chinese soldiers. The "small arms" type of warfare in this campaign is shown by the missile causing the wounds: bullets in 62 per cent and shell fragments, usually mortar, in 38 per cent. The fractures were evenly distributed as to side and fairly evenly as to the segment of the shaft involved: 34 per cent in the proximal third, 19 per cent in the middle third, and 47 per cent in the distal third.

Ninety-three per cent of the wounds were débrided in forward hospitals, the average time of operation being 10.4 hours following injury. Débridement was performed within the first twelve hours in 69 per cent of all the injuries. Sulfanilamide was applied locally to every wound at the time of the primary operation, and oral sulfonamides were given to all patients before admission to this hospital.

In 80 per cent an abduction plaster spica was used for temporary immobilization during evacuation to this installation. Many of these were broken at the shoulder on arrival. In only 10 per cent was a hanging plaster used for immobilization during evacuation. The average interval before arrival at this hospital, after a litter haul of varying distances and an airplane ride of over 100 miles, was 3.5 days.

Radial nerve paralysis was found in association with 33 per cent of the fractures, and median nerve paralysis in 7 per cent. There were no ulnar nerve injuries in this series. Evidence of circulatory insufficiency was present on admission in seven instances. In three the brachial artery had been injured. In the remaining four, constriction by an unpadded circular plaster, usually in the region of the elbow, was the cause of the ischemia. In no instance did gangrene result, but in two the ischemia was of sufficient duration to produce residual fibrosis and paralysis.

The hanging plaster was used for the definitive treatment of 80 per cent of the fractures. The remaining 20 per cent were treated by other methods (abduction plaster spica in 15 per cent, and skeletal traction with a Kirschner wire through the olecranon in 5 per cent) because of:

1. Bone loss of more than one inch (abduction spica)
2. Very high humeral fractures usually with associated injury to the shoulder joint (abduction spica)
3. Marked abduction of the proximal fragment (abduction spica)
4. Nonambulatory patients (skeletal traction)

The fractures were immobilized until there was x-ray evidence of bone union. This occurred on an average in 8.8 weeks. In four instances union occurred only after immobilization for 16 weeks.

Osteomyelitis occurred in five (8.3 per cent). In all cases it was localized and mild, and in no instance did it cause nonunion. Seven fractures had bone loss of more than one inch. The only five instances of nonunion (8.3 per cent) occurred in this group.

There were two deaths in this series. One was due to encephalitis of unknown etiology, and was unrelated to the fracture. At autopsy the fracture site was clean, and there was no evidence of embolism. Secondary hemorrhage three weeks after injury caused the second death.

OBSERVATIONS

On the basis of our experience with the sixty gunshot fractures of the humeral shaft, certain opinions regarding their management have been formed.

Primary Treatment and Evacuation.—Although it is generally agreed that débridement should be performed as early as possible after injury, an interval of several days is not a contraindication to operation. Late débridement, from one to several days after injury, has appeared to be of value in preventing or limiting infection, and in shortening the period of wound healing. It seems probable that the establishing of free drainage and removal of unattached bone fragments, necrotic tissue, and foreign bodies, even in the presence of localized infection and inflammation, will aid in preventing the development of osteomyelitis. With the aid of sulfonamides, the danger of causing invasive infection by excising necrotic tissue in the presence of inflammation is minimal.

It is questionable whether the use of an abduction spica for evacuation of these fractures, as was done in 80 per cent of those admitted to this hospital, is justifiable. Many of the spicas had broken at the shoulder during transportation and, on arrival, these patients had considerable pain because of motion at the fracture site. Not infrequently wide abduction in a spica caused marked medial angulation. This could be corrected in almost every instance by merely dropping the arm to the side, as shown in Fig. 1.

Humeral fractures can be efficiently immobilized for evacuation in a hanging plaster. In patients who must travel in the recumbent position it is advisable to fix the plaster to the body with a few turns of the bandage. Advantages of the hanging plaster for evacuation are simplicity of application, saving of time, economy in the use of plaster, greater comfort for the patient, and, in most instances, better position of the fragments. The increased comfort of the patient when a shoulder spica was changed to a hanging plaster was impressive.

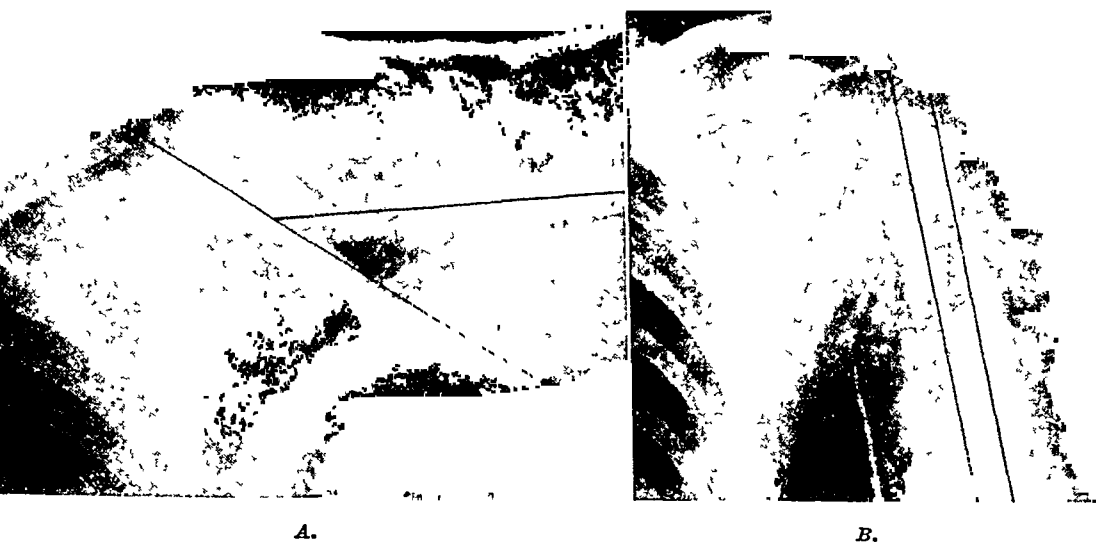


Fig. 1.—Gunshot fracture of the proximal third of the humeral shaft. *A*, Position on admission in a 90 degree abduction spica, 37 degrees medial angulation. *B*, Perfect alignment obtained by merely dropping the arm to the side in a hanging cast. (Photograph by First Medical Museum and Arts Detachment.)

Treatment of the Fracture.—The characteristic displacements of the fragments found in simple fractures of the humerus were not often seen. External angulation in fractures of the proximal shaft was not common and abduction was rarely necessary to correct this deformity. Several fractures of the distal third were externally angulated. Pronation of the forearm as suggested by Böhler² was very helpful in correcting this (Fig. 2). In our experience it has not been necessary to keep patients treated with a hanging plaster in an erect or semi-reclining position during sleep for the first 10 to 14 days after injury, as recommended by Shands.³ In Chinese patients, all of whom refused to sit up while sleeping, the efficiency of the hanging plaster in reducing the fracture and in maintaining good position of the fragments was not decreased. Whenever possible, the hanging plaster should be applied with the patient in a sitting position. If anesthesia is necessary, brachial plexus block is useful since the patient may remain upright.

The recent suggestion of Churchill⁴ that the wounds of gunshot fractures be closed by delayed primary suture within ten days after injury has impressed us, for the early conversion of a compound fracture to a simple fracture is highly desirable. This procedure presupposes thorough débridement and a wound free from infection.

Nerve Injuries.—Because nerve injuries are responsible for most of the disability resulting from these injuries, their treatment is of greatest importance. It is now generally agreed that the highest incidence of nerve regeneration is obtained when repair is performed within the first few weeks after injury.

This necessitates close cooperation between the orthopedist and neurosurgeon. Whenever possible, nerves should be sutured at the time of delayed primary closure, if this is done.

Overzealous splinting of the wrist and fingers in extension for radial nerve injuries may result in fixation in this position. Splints for radial nerve palsy should be removable so that the wrist and fingers may be moved through their full range of motion several times daily. No splinting at all, with frequent active and passive joint motion, is better than continuous splinting. Suspension of the fingers and wrist by rubber bands to a "banjo" ring incorporated in the plaster is an excellent method of preventing deformities due to radial nerve injuries.

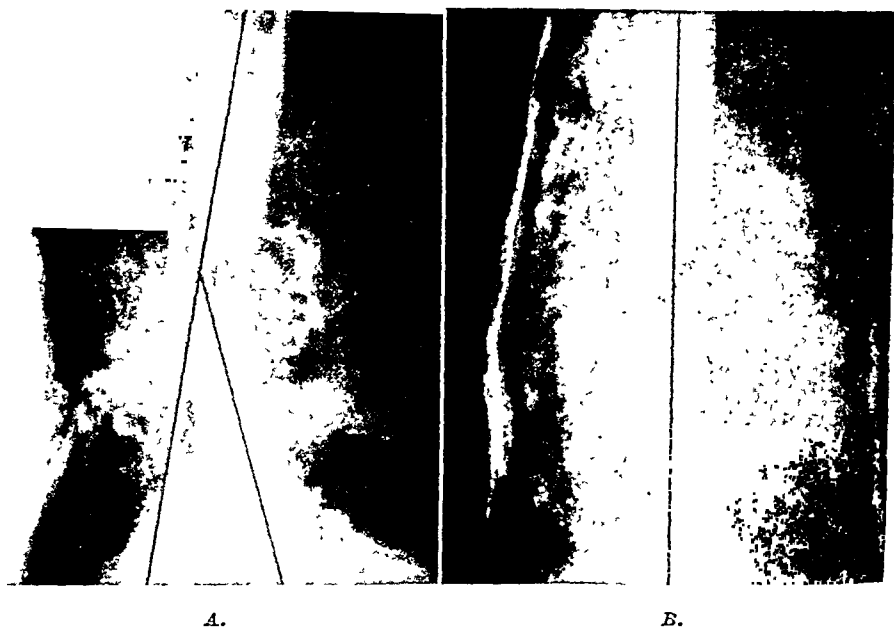


Fig. 2.—Gunshot fracture of the distal third of the humerus. *A*, On admission with the forearm in supination; 25 degrees external angulation. *B*, Perfect alignment obtained by merely pronating the forearm. (Photograph by First Medical Museum and Arts Department.)

Circulatory Impairment.—The occurrence of circulatory embarrassment in seven instances emphasizes the importance of this complication. The commonest cause was constriction, usually at the elbow, by an unpadded circular plaster. Following splitting of the plaster, adequate circulation returned in all but one. In this instance there was residual partial paralysis of the hand due to the temporary ischemia. This complication can always be prevented by adequate padding and by frequent inspection for circulatory impairment by the personnel concerned in evacuation. At the first sign of ischemia the plaster must be split through its entire length and spread.

In three instances the brachial artery was injured. In two the artery had been ligated at the time of débridement and signs of ischemia were present on admission. Gangrene was feared in both, but, following elevation of the extremity and repeated blocking of the stellate ganglion with procaine, the ischemia disappeared and viable extremities resulted. In one there was moderate residual ischemic paralysis. In the remaining instance, arterial injury was not suspected until a secondary hemorrhage occurred on the tenth day after injury. This case emphasizes the fact that a palpable radial pulse does not exclude major arterial damage. Because the errors in management of this case are instructive, it is briefly described here.

CASE REPORT

A 27-year-old Chinese soldier was admitted in a plaster spica 3 days after a perforating bullet wound of the proximal humerus. He was in good general condition in spite of a hemoglobin of 8.0 Gm. The radial pulse seemed to be normal. Blood transfusions were given and a hanging plaster was applied. On the tenth day after the injury the wound bled an estimated 150 c.c. beneath the plaster. When the plaster was removed, no evidence of active bleeding was found, and the wound was not explored. After the wound remained dry for two days, the plaster was reapplied. Convalescence was then uneventful until the twenty-first day when, during the night, a sudden massive hemorrhage occurred from a divided brachial artery and death resulted before the plaster could be removed.

Secondary hemorrhage, no matter how minor, must always be considered an absolute indication for immediate exploration of the wound.

Osteomyelitis.—Osteomyelitis occurred in only five cases (8.3 per cent). In every instance it was well localized and of short duration, requiring only simple removal of sequestra to effect healing. It seems probable that early and adequate débridement was chiefly responsible for this. The routine use of local and oral sulfonamides may have been a factor. During the campaign penicillin was not available. Nonunion was not caused, nor was union significantly delayed, by osteomyelitis.

Nonunion.—In all fractures which resulted in nonunion, there was bone loss of more than one inch. In each instance a plaster spica was used for treatment, and efforts were made at the time of application to approximate the fragments. Two fractures, each with bone loss of two inches, united by the use of this method. In no instance in which there was a minor degree of bone loss did the traction of the hanging cast predispose to nonunion. It is entirely possible that fractures with bone loss of more than one inch might have bridged as well with a hanging plaster as with a spica. Fractures in which nonunion is inevitable should be recognized as early as possible in order that neighboring joints may be given physical therapy prior to the prolonged immobilization associated with bone grafting.

CONCLUSIONS

1. Our experience has shown that gunshot fractures of the humeral shaft can be adequately and comfortably evacuated in a hanging plaster to a fixed installation, and, in our opinion, this is the method of choice.
2. The hanging plaster is highly satisfactory for treatment of these fractures in most instances. Traction by the plaster does not predispose to nonunion in cases with minor degrees of bone loss.
3. Associated nerve injuries occur in a high percentage of these fractures, and are the most frequent cause of disability.
4. Ischemia due to constriction by circular plaster is a constant danger. It can be prevented by adequate padding and, if circulatory impairment is imminent, by splitting and spreading the plaster.
5. Secondary hemorrhage, no matter how minor, is an absolute indication for immediate exploration of the wound.

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RADIOGRAPHIC DIAGNOSIS OF HERNIA INTO THE LESSER PERITONEAL SAC THROUGH THE FORAMEN OF WINSLOW

REPORT OF A CASE

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(From the Hollenberg Clinic)

THE rare but interesting condition of hernia into the lesser peritoneal sac through the foramen of Winslow is reviewed at length by Ullman.* In his section under diagnosis he states that a preoperative diagnosis of hernia through the foramen of Winslow has never been made. My investigation of the literature confirms this statement. In his conclusion he asks, "Will a preoperative diagnosis of a hernia through the foramen of Winslow ever be made and will it be differentiated from other internal hernias?"

CASE REPORT

Mr. C., 76-year-old Scottish farmer, came to my office at 6 P.M., Dec. 13, 1933, complaining of acute intermittent epigastric pains.

Previous Personal History.—He always enjoyed good health until the year before admission, when he began to suffer recurrent attacks of diarrhea. His illness began at 10 A.M. the morning of Dec. 13, 1933. The pain in the epigastrium was, at first, mild and recurred at long intervals, but was becoming progressively more severe when he saw me at 6 P.M. No flatus or feces had been passed since the onset of the illness. The severe abdominal pains were localized to the upper part of the abdomen. There was also tenderness around the umbilicus. During an acute attack of this colic he doubled up with pain, applying counterpressure to the abdomen with his hands. The attack lasted about two minutes and then gradually subsided. Examination of the abdomen revealed no bulging or any external hernia. The clinical picture was that of an acute obstruction. No peristaltic waves were visible during the attack of colic. Palpation over the epigastric region elicited excruciating pain. He had not vomited since the onset. There was marked epigastric resonance on deep percussion; there was also some fullness over the epigastrium. Being of the opinion that the obstruction was high up, I gave him barium and took the plate illustrated in Fig. 1. The lesser curvature presented two parallel crescentic outlines. It also showed the stomach hugging a rounded gas-filled mass. This led me to suspect that there was a hernia into the lesser peritoneal cavity, therefore the patient was sent to the Winnipeg General Hospital. There he was given four enemas with the hope of overcoming the obstruction, but with no avail. He was then given a barium enema. The result is shown in Fig. 2. The stomach still contained some barium; some of it had passed into the small bowel which appeared distended and pipelike, typical of a distal obstruction. The barium enema outlined the rectosigmoid descending and the left half of the transverse colon where the barium shadow abruptly ceased. The cecum ascending colon and right half of the transverse colon were not visible. There was a large, dark, rounded, gas-filled mass hugged by the stomach, and a gas distended bowel leaving this mass or being pinched off in the region of the foramen of Winslow could be seen. This confirmed the diagnosis of hernia of the cecum ascending and the right half of the transverse colon into the lesser peritoneal cavity through the foramen of Winslow. This diagnosis was recorded on the operative sheet before the abdomen was opened.

Operation.—Operation was performed at 10 P.M. that night. The abdomen was opened through a right upper rectus incision. On investigation, the stomach was found to be hugging a large tympanitic mass which was movable, tense, and balloonlike in consistency (Fig. 3). The gastrohepatic omentum could be moved over the mass freely. No cecum or ascending colon could be found. The tip of the appendix was located high up on the right side under the liver. The right half of the transverse colon was missing. Only the left half could be seen. When this was traced to the right it ended abruptly in strong adhesions to the gall

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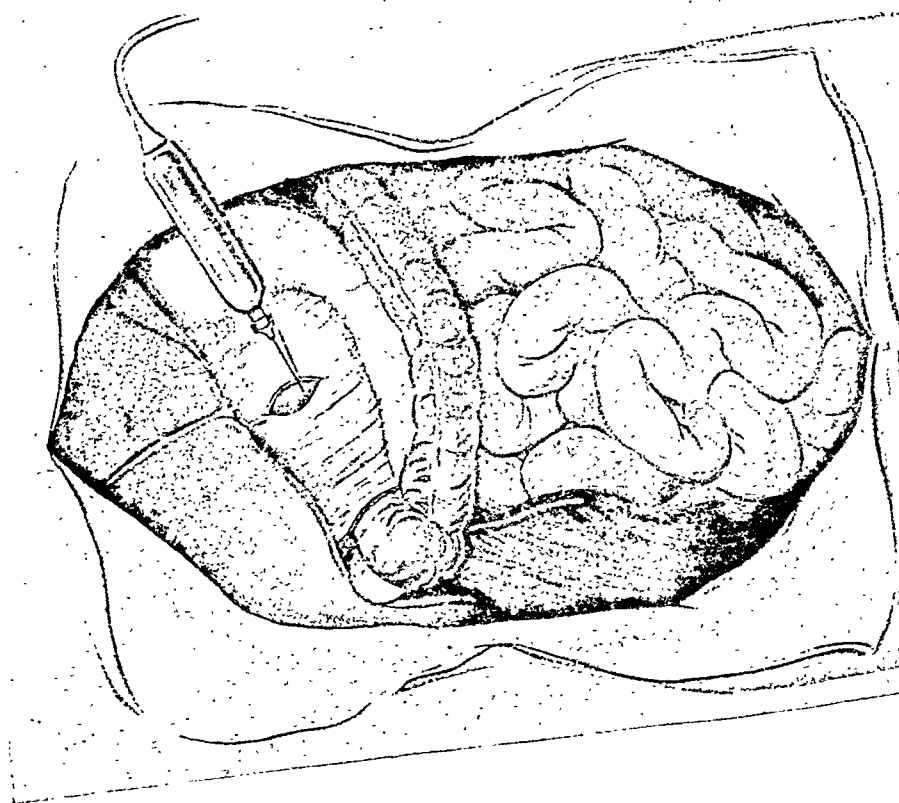
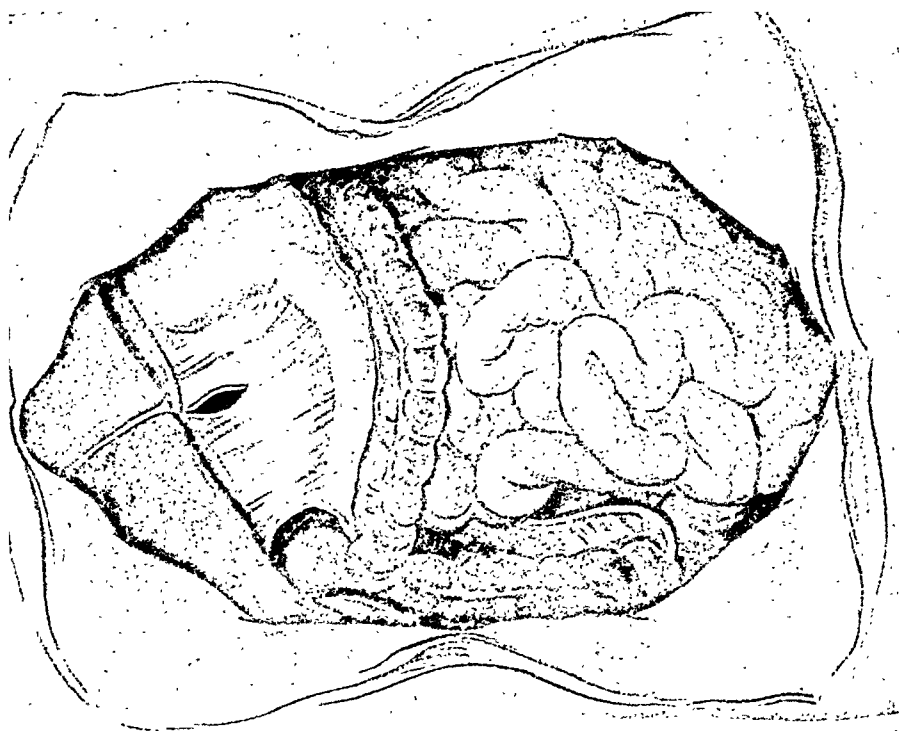
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Fig. 1.



Fig. 2.



bladder and liver. This exploration confirmed the preoperative diagnosis. The left half of the transverse colon appeared to run straight into the liver. I attempted by traction on the colon and pressure over the lesser sac to deliver the incarcerated bowel without success. I then opened the lesser omentum and deflated the cecum by means of a needle attached to suction closing the hole in the cecum with a purse string and reinforcing it with Lembert sutures. The herniated bowel was then easily reduced through the foramen of Winslow (Fig. 4). The opening in the gastrophatic omentum was closed. No attempt was made to close the foramen of Winslow. The cecum was tacked down in the right iliac fossa. The abdominal cavity was closed in the usual manner. The patient did well for two weeks. On December 27, his temperature became hectic, associated with chills. The pulse went up to 120 and respirations were 24. The left leg became swollen and painful. A diagnosis of thrombophlebitis of the iliac veins was made. His condition became progressively worse. There were no positive physical findings in the chest. He died December 29. The clinical diagnosis as to the cause of death was pulmonary embolism.

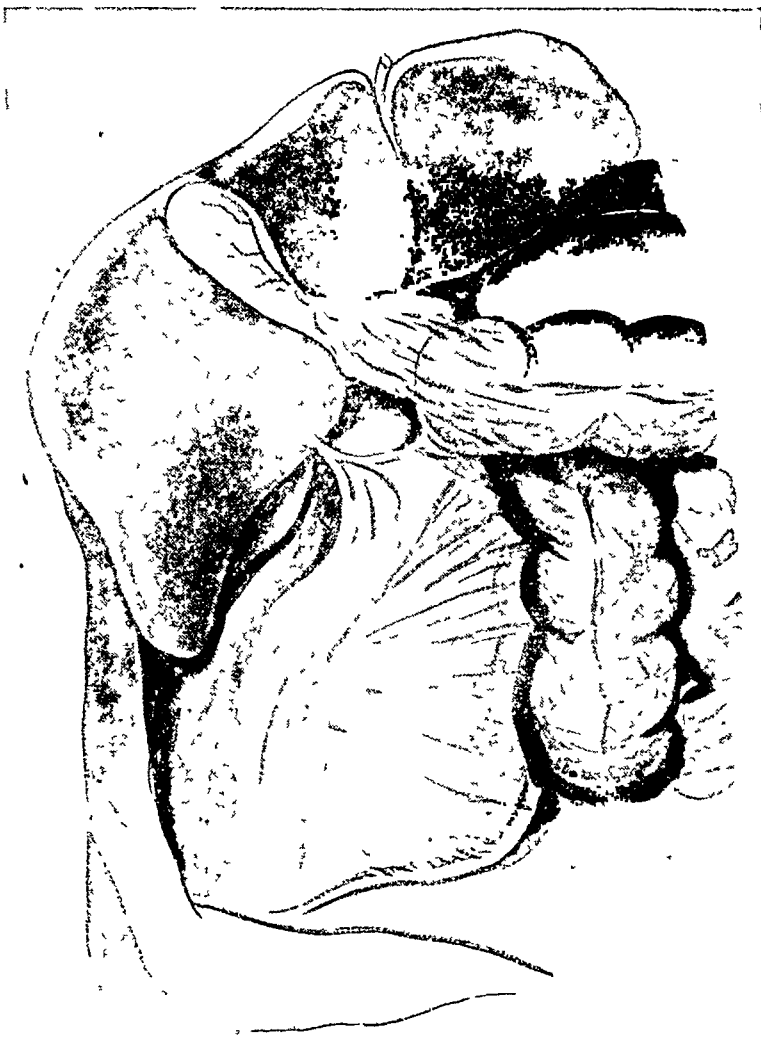


FIG. 5.

Autopsy Report.—Autopsy revealed a very thin man, 76 years of age whose left leg was very much larger than the right. It was not discolored. The pleural cavities showed no fluid. There were old adhesions over both lateral surfaces. The left lung weighed 525 Gm. There were apical scars. The lung was soft and crepitant throughout, showing quite marked emphysema. The main pulmonary artery contained fluid blood, but in three of the large branches there were firm masses of adherent thrombus. There were no infarcts in the lung. It showed only edema and congestion with some collapse in the posterior portion. The right

lung weighed 550 Gm. An apical scar and quite marked emphysema were present. There was a large adherent thrombus filling the upper portion of the branch of the pulmonary artery to the lower lobe. There was no infarct in the lower lobe, but there was a small one 1.5 cm. in diameter in the upper lobe just below the apex. The rest of the lung was congested, and there was some collapse of the posterior portion. There was no fluid in the abdominal cavity and the foramen of Winslow was large, admitting three fingers (Fig. 5). The right lobe of the liver was large and there was a transverse depression partially constricting off the lower half of the lobe. The gall bladder was covered with adhesions and was adherent to the transverse colon. The cecum was distended, unusually mobile, and was adherent to the omentum. The appendix was long, retrocecal, and tied down. The left iliac vein was filled with a firm adherent thrombus. The right vein was empty.

Summary of Autopsy.—Atheroma of aorta, pulmonary emphysema, pulmonary embolism, enlargement of the foramen of Winslow, and thrombosis of the left iliac vein. The thrombosis in the iliac vein was responsible for the embolus which lodged in the lung and caused death.

Probable Mechanism of Production.—The adhesions of the gall bladder and liver to the center of the transverse colon, and the fact that the right lobe of the liver was elongated a hand breadth below the costal margin, probably produced this rare hernia. The medial, spoon-shaped surface of the right elongated lobe of the liver directed the abdominal contents into the foramen of Winslow. The patient had recurrent attacks of diarrhea in the year before admission. These may be accounted for by the partial obstruction produced by the adhesions from the gall bladder across the middle of the transverse colon. The repeated attacks elongated the mesentery of the ascending colon until the right half of the transverse colon and ascending colon were forced into the lesser peritoneal sac and strangulated by the foramen of Winslow.

SUMMARY

The first case on record of hernia through the foramen of Winslow wherein a preoperative diagnosis was established from the radiologic investigation is presented.

EXTRADURAL ANESTHESIA

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CATHELIN, in 1901, was able to block the sacral and coccygeal nerves by injecting the anesthetic substance into the sacral canal, for peridural sacral anesthesia (caudal anesthesia) was limited to operations on the perineum. This led some surgeons to try the use of some different technical details in performing sacral anesthesia, so that they would be able to use it for operations in the abdomen. Larger doses as well as larger volumes of the anesthetic solution were employed, and the Trendelenburg position was tried in an effort to force the diffusion of the anesthetic solution to a higher level.

Extradural anesthesia, with the technique as used at present, was performed for the first time in 1920 by the Spanish surgeon, Pages, who also presented the first paper on this subject based upon forty-three observations with only two failures.¹ His researches were abandoned and forgotten after his death.

In 1931, at the Italian Congress of Surgery, Dogliotti described a "new method" of anesthesia to which he gave the name of "segmental peridural

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anesthesia," claiming for himself the priority of the discovery. In 1932, he presented his results to the American Congress of Surgery.²

Gutiérrez, in 1932,³ called attention to the negative pressure of the extradural space (discovered in 1929 by Heldt and Maloney⁴) as a means of help in being certain of the exact location of the needle. Thus the "sign of the droplet" (also known as "Gutiérrez's sign") became known. Extradural anesthesia (the name given by Gutiérrez) has been also called "anesthesia of Pages," peridural anesthesia, segmentary anesthesia, epidural metameric anesthesia, or epidural anesthesia. Since my arrival in the United States in October, 1944, I have visited several hospitals, and I have not yet seen an operation performed with extradural anesthesia.

In 1938, when I spent some months working and studying surgery in Argentina, my attention was called to this method as used in the surgical service of Gutiérrez. I saw difficult operations performed with it, and during the post-operative course the patients felt none of the discomfort that results from anesthesia as it is usually given. I began a study of this new method of administering anesthesia and on my return to my own country put the knowledge to practical use in the hospital and with my private patients. An account of its effects in the first 100 cases was published in 1939 as a thesis, which I submitted as partial fulfillment of the requirements for promotion to the rank of Docente (Associate Professor) in the Medical School of the University of Brazil. Since then the number of cases involving the use of extradural anesthesia has grown steadily and I have observed its effects on more than 600 patients. I am a most enthusiastic believer in the value of this particular kind of anesthesia, because I am sure that it is one of the best available to the surgeon when he needs an anesthesia capable of long duration, but with as little toxic effect on the patient as possible. Before 1938, extradural anesthesia found little support among the surgeons of Rio de Janeiro. The few who had the occasion to try it considered it definitely inferior to the methods already in general use. I was happy to be able to call the attention of others to my excellent results and now many surgeons of Rio de Janeiro are relying on extradural anesthesia for serious operations.

I would like to express my views on extradural anesthesia and point out some of its results, based on my own case records.

I will not lose time with preliminary discussion of surgical anatomy or the physiology of the extradural (peridural) space, because such matters are well known. For reasons of clarity, however, I will divide my account into seven parts: Comparative study of extradural and intradural (spinal) anesthesia, technique, anesthetic solutions, locale (site) of puncture, evolution of the anesthesia, failures and accidents in its use.

COMPARATIVE STUDY OF EXTRADURAL AND INTRADURAL (SPINAL) ANESTHESIA

In intradural anesthesia, the anesthetic is injected into the subarachnoid space inside the duramater; in extradural, the solution is introduced into the extradural (peridural) space just outside the dura. The anesthetic injected into the extradural space does not come in contact with the cerebrospinal fluid, which obviates the danger both of toxic effect on the bulbar center and of resultant respiratory syncope. In extradural anesthesia the spinal ganglia, the sympathetic and spinal nerves, and the dura associated with the radicular nerves are anesthetized.

The changes of blood pressure after extradural anesthesia have not the same dangerous aspects that they have with intradural. Arterial hypotension, the dread of anyone giving intradural anesthesia, occurs much less often with the extradural method. In 600 cases, with blood pressure determinations made immediately before and after administration of the anesthetic and supportive drugs, at the beginning and end of the operation, and during twenty-four to forty-eight hours in the postoperative course. I made the following observations: In 66 per cent, the blood pressure rose; in 25 per cent, it fell; and in 9 per cent it showed no alteration. When the pressure falls, I use a supportive drug (ephedrine, 0.05 Gm.). This may also be used prophylactically.

The duration of the extradural anesthesia is longer, its range of action is wider, and accidents during and after its administration occur less frequently than in anesthesia of any other kind. Using an average of 45 c.c. of a 2 per cent solution of novocain, some patients have had anesthesia lasting more than four hours, but the average duration ranges from two to three hours. After this period of surgical anesthesia there is relatively long absence of sensitivity, very profitable for the patient because he does not feel pain in the postoperative period. Another great advantage of extradural anesthesia is the rarity of post-anesthetic reactions, such as headache, vomiting, and urinary retention. Late postoperative reactions, even after prolonged anesthesia, are likewise reduced. All these complications are quite usual after intradural anesthesia.

A modern and efficient surgeon must know every type of anesthesia, practically as well as theoretically, because each has its peculiar indications. A thorough examination of the patient and, based on that, the selection of the kind of anesthesia best for the particular case, should eliminate failure and accident on the part of the surgeon and anesthetist. Accidents during or after extradural anesthesia depend somewhat on the skill of the anesthetist. It need hardly be remarked that in nervous and anxious patients, in those in a malnourished, cachectic, or septic state, and in those with spinal deformities or ossifications of the interspinal ligaments or ligamenta flava, this method is not effective.

TECHNIQUE

The extradural space can be reached by the use of either of two techniques, the indirect or direct punctures. In the first, the needle is advanced until it perforates the duramater, which is indicated by the reflux of the cerebrospinal fluid. The needle is then withdrawn slowly until there is no reflux of the liquor and the point rests in the extradural space, where the anesthetic is injected. By the direct process, the anesthetist tries to reach the extradural space without perforating the duramater. Each time that he fails to do so, and perforates the dura, he withdraws the needle and makes another puncture in another interspinal space. This direct process is more correct and less dangerous, because with it there is no possibility that the anesthetic might penetrate the subarachnoid space through the opening in the dura.

The puncture is made with a special needle (the best is Gutiérrez's needle) in the area between the seventh cervical and fifth lumbar vertebrae, as required, with the patient in a sitting position. There are several signs to indicate that the needle is in the extradural space, but the best is the "sign of Gutiérrez" or the "sign of the droplet," which is based on negative pressure in the extradural space. After introducing the needle, the anesthetist progresses slowly, watching for the "sign of Gutiérrez." After passing through the superficial planes, with

the special needle, the anesthetist withdraws the stylet from the needle and fills the latter with the anesthetic solution in such a way that he leaves a drop of the solution hanging from the outer receptacle of the needle. He then advances the needle, pushing as slowly as possible, and when the epidural space is reached, the drop is aspirated inward. In some cases, there is only an oscillation of the drop, but usually a perfect suction is observed. With this sign, and the assurance that the point is in the extradural space, 10 c.c. of air are injected to separate the dura from the end of the needle. The anesthetist then injects 5 c.c. of anesthetic solution and waits five to ten minutes. The latter precaution is essential to ascertain whether the dura has been punctured. If it has, the specified amount of anesthetic is sufficient to produce intradural (spinal) anesthesia. If, after this time, no signs of anesthesia are noted, the rest of the solution is injected. The amount of the anesthetic solution depends upon its concentration and the duration of the operation.

Aside from the sign of Gutiérrez, the anesthetist may be guided by the sensation of having penetrated the ligamentum flavum and by the lack of resistance to the injection of the solution when the needle is in the extradural space. The distance between the skin and the extradural space varied from 3 to 7 cm. The sign of Gutiérrez was positive in 89 per cent of my observations. When the sitting position cannot be maintained, the patient may remain in the lateral position. However, in the latter position the technique is more difficult.

ANESTHETIC SOLUTIONS

The drugs used for extradural anesthesia are many. The concentration of the solution should be the same as a 2 per cent solution of novocaine. I have experimented with several solutions, including 1 per cent and 2 per cent novocaine (procaine), a 2 per cent solution of seurocaina, a 2 per cent solution of pantocain (pontocaine), a 0.1 per cent solution of percaïne (nupercaine), and "Gutiérrez' mixture." Of the various solutions used for extradural anesthesia, Gutiérrez' mixture (0.5 neotutocaina [pontocaine] and 0.50 novocaine [procaine]) has proved the most satisfactory. A very important matter, if the anesthetist is to avoid failure, is the sterilization of the anesthetic mixture. Novocaine changes easily under heat, and the sterilization is delicate. Gutiérrez' mixture must be sterilized by tindalization (fractional method) for one-half hour, four to five times, in a maximum temperature of 70° C.

The anesthetic solution is dissolved in 50 c.c. of physiologic saline solution, and ten drops of adrenalin added. The adrenalin produces vasoconstriction in the extradural venous plexus, delaying the absorption time of the anesthetic and prolonging its duration. Immediately after the anesthesia is produced, 3 c.c. of caffeine are injected subcutaneously to prevent vomiting and nausea from the novocaine intoxication. An interval of twenty minutes is desirable between injection of the anesthetic agent and beginning the operation.

In my series, the amount of solution ranged from 20 c.c. for appendectomy in a child to 46 c.c. for a gastrectomy which lasted two hours and forty-five minutes.

POINTS OF PUNCTURE

For operations in the neck and thorax, the puncture is made between the seventh cervical and first thoracic vertebrae. A puncture between the eleventh thoracic and third lumbar vertebrae produces anesthesia for operations in the genitourinary field and on the sympathetic nerves and digestive tract. To anes-

thetize the perineum and lower extremities, the puncture is made between the third and fifth lumbar vertebrae. In such cases the patient is left sitting for fifteen minutes after the injection.

DEVELOPMENT AND DURATION OF THE ANESTHESIA

The effect of extradural anesthesia is not as immediate as that of intradural. Ten minutes after injection there is a large zone of anesthesia which continues to enlarge for about twenty minutes, and sometimes extends from the chin to the feet. The diffusion of the anesthesia is variable, but generally it depends upon the concentration of the solution, the amount injected, and the point of puncture. Likewise, its duration depends upon the strength of the anesthetic, the substance used, and the dose injected. The most successful results, both of development and duration, in my experience, were obtained with Gutiérrez' mixture. With an average dose of 40 c.c. of anesthetic solution, I have had anesthesia for two and one-half hours or more.

As stated earlier, extradural anesthesia is indicated for operations in the neck, thorax, abdomen, and extremities, and causes few postoperative complications, but it is contraindicated in nervous or anxious patients, in those in a malnourished, cachectic, or septic state, and in those with spinal deformities or ossification of the interspinal ligaments or ligamenta flava.

For some time I have been using, with very good results, a sedative medication just after finishing the anesthetic injection.

My experience with the effects of extradural anesthesia on children is limited, since I have had only two cases. I have, however, records of its successful use on fifteen patients older than 70 years, and on one 85 years of age.

FAILURES AND ACCIDENTS

Failures and accidents with extradural anesthesia are due largely to inexperience and improper technique. The skill of the anesthetist is a determining factor as is occasionally, also, the quality and amount of the anesthetic solution. Syncope may occur during induction, although no such reaction occurred in my series. At most, there was some nausea in a few patients. Owing to insufficient concentration of the anesthetic in a few cases at the beginning of the series, supplementary general anesthesia was required, and in a few others, because of the patient's extreme nervousness, a different form of anesthesia had to be resorted to. There was only one complete failure of anesthesia.

CONCLUSIONS

1. Extradural anesthesia is one of the most satisfactory, because it meets many of the requirements of a good surgical anesthesia with a minimum of dangerous effects to the patient.

2. An important recommendation for extradural anesthesia is the rarity of postanesthetic reaction.

3. Late postoperative reactions, even after prolonged anesthesia, are likewise reduced with this method.

4. The "sign of Gutiérrez" or "sign of the droplet" is the best indication that the needle is in the extradural space.

5. Injection of the anesthetic solution must be made as slowly as possible, and always in fractionated amounts.

6. Twenty minutes must elapse after injection before the surgeon may begin the operation.

7. Accidents during or after anesthesia depend somewhat upon the skill of the anesthetist.

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SEMIELASTIC COTTON GAUZE BANDAGE FABRIC

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THERE has been a long-felt need for a surgical gauze with a moderate amount of elasticity so that it will stretch or "give" while being applied and so exert moderate pressure. A gauze has recently been developed which has these plus other unusual and useful properties. It has stretchability and elasticity which make it somewhat self-fitting and self-tightening; the elasticity, together with a nonslip surface texture, causes a bandage made from it to cling rather than to tend to loosen while in place. The new fabric is all cotton, is in effect a preshrunk gauze, and has no similarity to conventional elastic bandages.

Bandages made from the new gauze have been submitted to several hospitals for clinical tests, in some instances by request. Reports have been very favorable, but the number of requests for additional quantities constitutes the best evidence that this bandage meets a real need. It has been on trial for over one year to the extent of about 9,000 unit strips, more than half of which have been used at the U. S. Naval Hospital in New Orleans where this bandage has supplanted all others for securing dressings about freshly operated joints.

This new type of bandage has properties of general interest, as well as specific advantages, which have recommended it for continued use at the Naval Hospital, especially in orthopedic surgery, and for various other purposes. First, it meets the general requirement that it can be sterilized by any of the standard recognized techniques without its special characteristics being affected. Next, its light weight is also of general interest because a bandage of given bulk in terms of thickness may weigh one-fourth less than one of ordinary gauze of 44 by 36 thread count.

The superior ability of this bandage to conform to the contours of the body and to remain in place makes it ideal for securing splints of all types.

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Fig. 1.—Application demonstrating special properties of semielastic gauze.

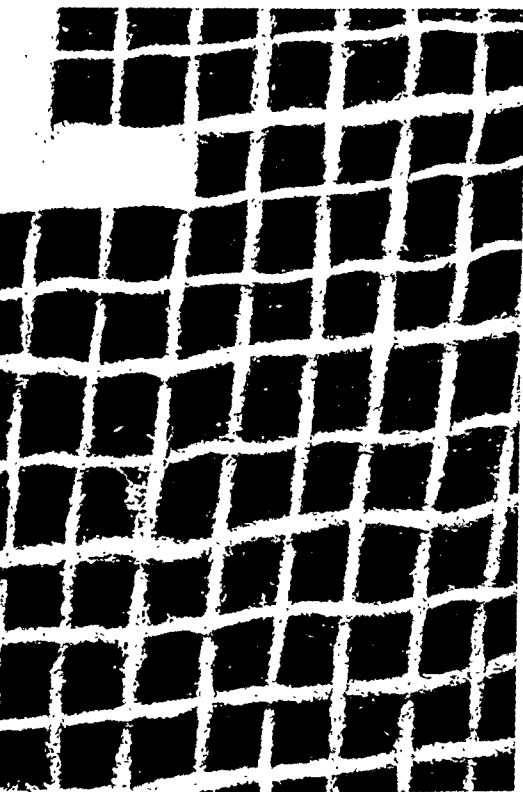


Fig. 2.

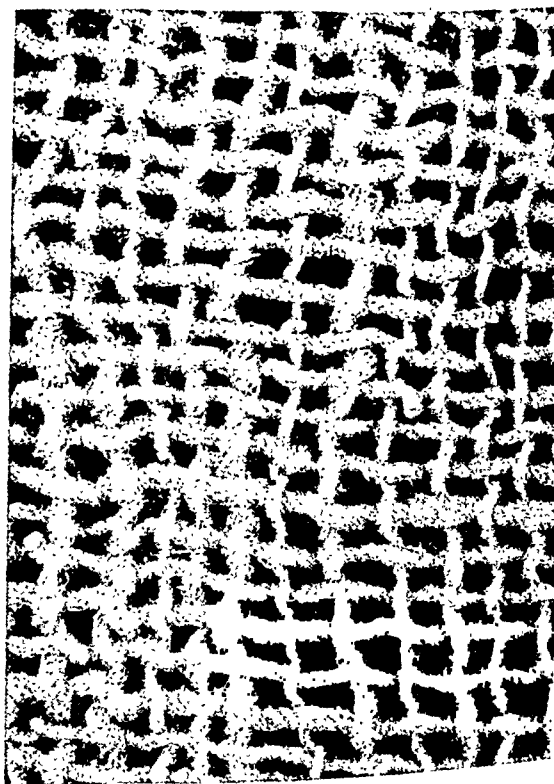


Fig. 3.

Figs. 2 and 3.—Ordinary gauze and semielastic gauze made from it. Views enlarged to the same scale.

The bandage can be used in conjunction with plaster without fear of "drawing" in any plane. In fact, its preshrunk character allows use either over or under plaster without danger of necrosis from cutting into the skin after drawing. It has proved very satisfactory for binding plaster splints and does so without adding appreciable weight to them. The bandage is unusually suitable for pressure dressings including use for burns, varicosities, and skin grafts. It is particularly good about joints where it is most desirable that the bandage should not slip. It should be emphasized that a steady even pressure can be applied easily and maintained for a prolonged time with this bandage. This is true whether there has been moderate swelling or whether swelling has subsided subsequent to bandaging. Because of its elastic properties and clinging power, the bandage tends to remain in situ, which is imperative about joints when the patient is ambulant or is permitted or encouraged to use the joint.

The only defect of any consequence noted in over one year's trial has been a mild tendency to gather on the short side of a joint when used in applying a spica type bandage. However, this is no more so than in conventional types and any mild tendency to chafe can be readily controlled by placing a pad in the axilla or groin. With these bandages, there has been noted also a tendency to gather about the torso or chest, but this can be largely controlled by the use of transverse adhesive strips at the time of application.

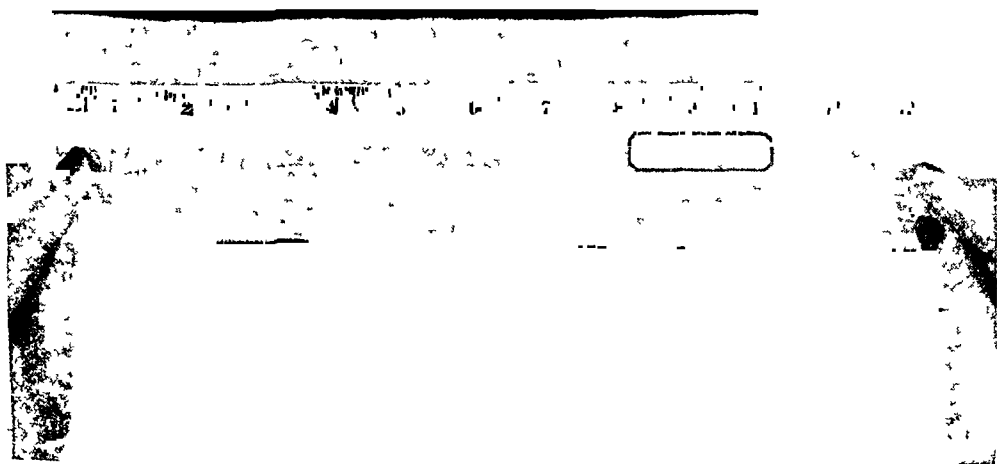


Fig. 4.—Semielastic gauze easily stretches 20 per cent

This bandage fabric is an outgrowth of the well-known fact that immersion in concentrated sodium hydroxide solution causes cotton to shrink, primarily because it swells the fibers. The tendency of the swelling fibers to expand within the spiral structure of the yarn in the cloth causes the yarn to shorten which, in turn, causes the cloth to shrink. If the material is of suitable open weave like the lighter weights of surgical gauze, pronounced crimps and kinks are also formed which increase the shrinkage but make the goods easily stretchable and somewhat elastic. The complete effect is shown quite clearly in Figs. 2 and 3, which represent the original and treated gauze on the same scale. The shrinking, or mercerizing treatment, as it may be called, causes the yarn to expand in diameter and to become loose in construction, to shrink until the interspaces in the cloth are much smaller, and to form many crimps and kinks, some of which do not show because they are standing vertically to the plane of the fabric.

The ultimate result is that the cloth stretches easily under low tension, due to straightening of the yarns and tightening of their structure, but returns elastically, when released, to approximately its dimensions in the shrunk form. Most of the gauze prepared in this manner, if stretched 20 per cent, for example, from 10 inches to 12 (Fig. 4), has an average recovery of 15 per cent, to a new length of 10.5 inches. The elastic properties represented by these figures have proved very satisfactory for all around use. The surface irregularities, which are due to crimping and kinking, intermesh as each layer of a bandage or dressing is added, so that no layer can slip upon the others. Thus the bandage is interlocked, does not come apart readily, and also tends to stay in position.

The fabric as used in most of the clinical trials has been somewhat heavier than standard bandage material, but fewer layers are used. The weight can be modified by suitable selection of the initial gauze. Up to the present time the bandages have been made only on a rather large laboratory scale, but their special properties and general utility suggests that they be made available commercially.

COD-LIVER OIL OINTMENT IN SURGERY

TOPICAL APPLICATION

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COD-LIVER oil ointment has been used in this country for more than a decade and over a much longer period in Europe. Many who have tried it have continued its use. The purpose of this paper is to present the results obtained from the extensive use of cod-liver oil ointment in a large series of cases consisting of a variety of lesions.

REVIEW OF LITERATURE

In 1934, Löhr¹⁷ published his original paper presenting a series of cases, consisting of burns and a wide variety of clean and infected wounds treated with cod-liver oil applied topically. In the original and subsequent reports,¹⁸⁻²⁰ Löhr was enthusiastic and convinced of its superiority in the treatment of many surgical lesions. He was soon aware of the rapid liquefaction of nonviable tissue, its stimulating effect upon healing, and the minimal pliable scarring following its use. Löhr found cod-liver oil to be bacteriostatic and bacteriocidal.

Steel³⁰ found the cod-liver oil treatment to be very satisfactory for burns. He was particularly impressed by the reduction of pain. In 1936, Davson⁶ presented experimental evidence to the effect that cod-liver oil definitely stimulates the healing process. He found an increased infiltration of the surrounding tissues with scavenger and repair cells.

In 1931, Thompson and Sheard³¹ reported irradiated oil to have a decided bacteriostatic action. Puestow, Poncher, and Hammatt²⁷ treated experimental burns with tannic acid and cod-liver oil ointment. They found the healing time

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to be 25 per cent less when the latter was used. Kozanjan,¹⁴ Tumanskiy and Yatsevich,³² Pyke,²⁸ Daver,⁵ Mutschler,²⁴ Salzmann and Goldstein,²⁹ Iost and Koehergin,¹² Lauber,¹⁵ Proto,²⁶ Hayashi,¹⁰ Lichtenstein,¹⁰ Abramowitz,¹ Aldrich,² Heald,¹¹ Brandaleon,³ Clayton,⁴ MacCollum,²² and many others recommended the cod-liver oil ointment treatment for a wide variety of surgical lesions. Their observations correspond to those previously cited.

In 1941, Hardin⁷ published an excellent paper, giving a comprehensive review of the literature and presenting 346 additional cases in which the lesions were treated with the vitamin ointment. He reported the first cure of "Meleney ulcer" by the topical application of the ointment. Hardin recommended it as a "superlative method" of local treatment for burns and clean and infected wounds.

ACTIVE AGENTS AND EFFECTS PRODUCED

There is not complete agreement as to the active agents in cod-liver oil ointment or exactly what reaction takes place when it is applied topically to wounds. Lauber¹⁵ and Lundh²¹ concluded that vitamins A and D are absorbed and act systemically. Drigalski³³ and others thought vitamin A to be the active agent. Many are convinced that both vitamins A and D are essential and in order to produce the most satisfactory effect, they must be in the same proportion as that found in crude cod-liver oil. A few investigators believe the beneficial effect is due to the fatty acid content of the ointment. There is evidence that unsaturated fatty acids are related to the health and healing power of the skin. It can be stated with certainty that the same beneficial effect is not produced when the vitamins are given orally. There is probably an increased local vitamin requirement which is met by the topical application of the ointment.

Despite the disagreement concerning the active agents and the effects thereby produced, we know that cod-liver oil ointment is sterile, bacteriostatic, mildly bacteriocidal, and nonirritating; that it decreases pain, aids in liquefaction of dead tissue, and forms a thin pliable protective membrane on wound surfaces to which it is applied. Lauber¹⁵ presented experimental proof that a stimulating effect is produced upon epithelial and connective tissue cells. Clayton⁴ stated that cod-liver oil ointment produces an elastic membrane by interfascial precipitation of colloids from their aqueous state. It does not precipitate or "fix" proteins and therefore does not damage the remaining viable epithelial cells. This form of treatment decreases the necessity for skin grafting but when necessary it can be accomplished early because the ointment produces a clean granulating surface.

TABLE I. CLASSIFICATION OF 713 LESIONS TREATED WITH COD-LIVER OIL OINTMENT

WOUND		NO.
Burns		171
Major, treated with C.-L.O. ointment as the only local treatment	26	
Major, treated with C.-L.O. ointment secondarily	20	
Minor	125	
Denudation and avulsion type		307
Cutaneous and deeper structure defects following surgical procedures		101
Osteomyelitis		9
Acute	4	
Chronic	5	
Sloughing and draining abdominal		19
Chronic ulcerations (5 tuberculous)		24
Miscellaneous clean and infected		82

CLINICAL APPLICATION

In this series, 171 burns were treated by the topical use of cod-liver oil ointment, crude cod-liver oil, Gadoment,* and Vitamin A and D ointment.† Forty-six cases were of major severity. Twenty-six burns were treated with cod-liver oil ointment topically, as the initial and only form of local therapy. Twenty were treated with the ointment secondarily and after other forms of local therapy had proved unsatisfactory. Eschar-producing agents had been used as the initial form of local therapy in the majority of the twenty cases.

In many of the cases it was necessary to administer plasma and other familiar systemic measures before any consideration was given to local burn therapy. Treatment of the burned lesion itself was always considered of secondary importance and was carried out only after instituting treatment for shock or for its prevention.

Early in the series the more severe burns were thoroughly debrided under anesthesia but the majority were less thoroughly debrided following the administration of analgesics. After aseptic débridement and thorough flushing of the burned surfaces with warm saline solution, they were covered with cod-liver oil ointment-impregnated fine-mesh gauze. Firm or pressure dressings were then superimposed. Extremities readily lend themselves to pressure dressings, while firm dressings are as much as can be accomplished when other portions of the body are involved. Mechanic's waste proved a satisfactory form of pressure dressing. It is cheap and easy to sterilize. Infrequent change of dressing is recommended, as redressing often admits secondary infection. It is usually not necessary to change the original dressing in less than seven days and it may well be left untouched for much longer. Properly managed burns do not often become infected.

The twenty-six major burns receiving cod-liver oil ointment as the only form of local therapy responded favorably to the treatment as outlined. Many seemingly important observations were made on the patients during the course of treatment. They required considerably less sedation than patients treated with eschar-producing agents and noticeably less than those treated with petrolatum gauze. Infection was almost nil in those treated with cod-liver oil ointment and petrolatum gauze, while it was present to some degree in practically every case in which eschar-forming agents had been used. The healing time was ten days longer in the group in which tannic acid was used and four and one-half days longer in the one in which petrolatum was used. Scarring was considerably less and there were no contractures on the patients treated with the vitamin ointment. Severe scarring and frequent contractures were present in the group treated with eschar-forming agents. The explanation is that the eschar-producing agents destroy remaining islets of viable epithelial cells, which would act as regeneration centers, while cod-liver oil ointment produces no further injury to those cells.

In all fairness it should be added that it is very difficult to evaluate impartially all factors encountered in treating clinical burns. In many cases it is impossible to distinguish between second and third degree burns when first seen.

There was no greater need for plasma than in the control groups of twenty similar cases which the patients were treated with petrolatum gauze and twenty treated with tannic acid and other eschar-producing agents. Despite the claims

*Produced by the E. L. Patch Company, Boston, Mass.

†Produced by White Laboratories, Inc., Newark, N. J.

of those who favor eschar-producing agents, the loss of fluid from the burned surface is slight and of little importance as compared with the loss of fluids into the local and the uninvolved tissues. That has been substantiated by several previous writers.^{8, 9, 13, 23, 25} The diffusion of plasma into the tissues is the important factor leading to hemoconcentration and shock. At least theoretically, the ointment combined with pressure dressings would decrease the diffusion of plasma, thus reversing claims made by tannic acid advocates.

TABLE II. ANALYTIC COMPARISON OF TANNIC ACID AND COD-LIVER OIL OINTMENT IN THE LOCAL TREATMENT OF BURNS

COMPARATIVE POINTS	TANNIC ACID	COD-LIVER OIL OINTMENT
Control of pain	Questionable value	Definite value
Range of use	Limited	Applicable to entire body
Protective covering	Rigid eschar	Pliable membrane
Infection	Frequent	Infrequent
Scarring	Moderate to severe	Minimal to moderate
Contractures	Frequent	Absent
Dressings	Not necessary	Infrequent changes
Skin grafting	Frequent	Infrequent
(3rd degree burns)		
Fixation of tissue	Deep fixation with destruction of viable cells	None
Healing time	Prolonged	Shortened
Pressure dressings	Not applicable	Very applicable
Primary shock	No effect	No effect
Secondary shock	No effect	Of apparent preventative value
Untoward reactions	Not uncommon and may be very serious (liver necrosis)	None

Three hundred seven denudations and avulsion type wounds were treated by the topical application of cod-liver oil ointment or packing with ointment-impregnated gauze. Many of the wounds were rather severe, involving large areas of skin and subcutaneous tissues, and a number presented open muscle wounds. Due to loss of tissues it was impossible to close some of the wounds while others were grossly contaminated, contraindicating primary closure. The wounds were thoroughly debrided, flushed with a large quantity of warm saline solution, and cod-liver oil ointment was used as the only form of local therapy. Otherwise the patients were treated in the usual manner. The dressings were changed infrequently. Wound infections were uncommon and no severe infections were seen. The defects filled with healthy granulation tissue in a surprisingly short time. Healing time was five to seventy-five days, with an average of seventeen days for the group. Scarring was minimal to moderate. This form of treatment proved entirely satisfactory.

One hundred one cases with cutaneous and deeper structure defects, following surgical procedures, were treated in a similar manner. The wounds ranged from small cutaneous defects resulting from removal of moles to large deeper structure defects resulting from excision of pilonidal cysts and amputation of breasts and extremities which for various reasons could not be closed at the time of operation. The wounds were treated with the ointment gauze as the only form of local therapy. Infection did not develop in the clean wounds and quickly subsided in the infected ones. All wounds healed satisfactorily without skin grafting. Again, the surprising feature was the rapidity with which the defects filled with granulation tissue thus facilitating more rapid epithelization.

The cod-liver oil ointment treatment was used in nine cases of osteomyelitis. As recommended by Löhr,²⁰ the involved areas were widely incised, the pus evacuated, sequestra removed, wounds loosely packed with cod-liver oil oint-

ment gauze, large absorbent dressings applied, and the extremity immobilized in a plaster cast. No windows were cut in the casts. The casts were not removed or reapplied for approximately three weeks and in some instances the original casts remained undisturbed much longer. The treatment was satisfactory in this small series of four acute and five chronic cases of osteomyelitis of extremities.

Nineteen sloughing and infected abdominal wounds were treated by packing or injecting with cod-liver oil ointment. Three of the patients presented the typical sloughing and the undermining postoperative abdominal wounds, following appendectomy for perforated gangrenous appendicitis. Many forms of local treatment had been applied in each instance before resorting to cod-liver oil ointment. The wounds were either filled with the ointment or packed with impregnated gauze. In each instance healthy granulation appeared in the bottom of the wounds in five to seven days. All healed in four to nine weeks. Several other chronically infected abdominal wounds were treated in a similar manner with good results.

The vitamin A and D ointment treatment was used in a large variety of miscellaneous surgical lesions, such as: tuberculous ulcerations and sinuses, trophic, varicose, and other chronic ulcerations, large abscess and carbuncle cavities, frostbites, x-ray burns, donor and recipient skin grafting sites. It proved of particular value when applied to donor and recipient skin-grafting sites. The ointment gauze dressing can be changed easily without disturbing the delicate graft. Let it again be emphasized that dressings should be changed infrequently.

SUMMARY AND CONCLUSIONS

A series of seven hundred thirteen cases is presented. One hundred seventy-one were burns, with the remainder representing a wide variety of surgical conditions. Twenty-six burns of major severity were treated with cod-liver oil ointment as the only form of local therapy. The results were considered superior to results in similar groups in which treatment was with eschar-producing agents and petrolatum.

Cod-liver oil ointment is of real value in the treatment of burns and many other surgical lesions. This method of treatment has all the advantages of tannic acid in burn therapy but eliminates many of the disadvantages. It is nontoxic, nonirritating, and applicable to all portions of the body. The ointment is bacteriostatic, bacteriocidal, speeds up liquefaction of devitalized tissue, and stimulates epithelial and connective tissue growth. Minimal pliable scars result. The preparation is sterile, easy to prepare in the crude form, not expensive, and may be obtained on the market as a refined odorless product. No additional equipment is needed and no skill is required in order to apply this form of treatment.

Cod-liver oil ointment is presented as a simple and effective local dressing with a wide range of use.

Space does not permit detailed case reports which appeared in the original thesis.

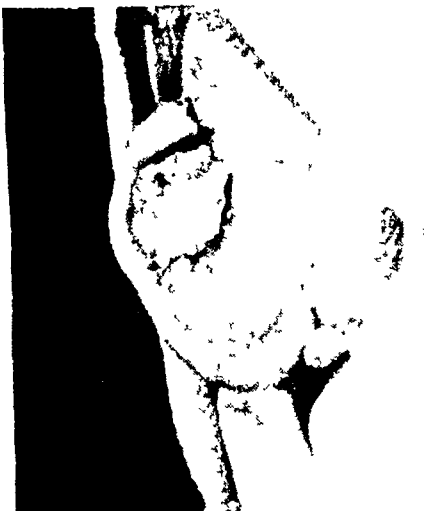
The author is deeply indebted to Dr. W. A. Coventry, Dr. T. O. Young, and Dr. E. L. Tuohy for their help in the preparation of this paper.

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B.



D.



E.

ed and lacerated ear on admission following injury by a
were covered with dirt, and cartilage was shredded. An
occurred, but no skull fracture was present. *B*, Healed
bridement and normal saline solution dressings. *C*, All
D, Skin loss replaced by full-thickness skin graft from

force and thus diminishes the violence of the blow. Except for this meager protective mechanism, the ear is helplessly exposed to lacerating and crushing wounds of all descriptions. Blows, bites, cuts and stabs of civilian life have their battle counterparts in more destructive missiles, shrapnel, bayonet or sword wounds.

Simple crushing injuries result in the formation of a hematoma which should be evacuated aseptically through a tiny incision in the antihelix fold, followed by a pressure dressing. Failure of such hematomas to absorb or repeated injuries of this type give cauliflower ear, the late treatment of which is difficult.

Lacerations without loss of substance should be treated by cleansing, lavage, and conservative débridement. A "tongue-and-groove" joint of cartilage and overlying soft tissue is fashioned to prevent notching at the site of through-and-through lacerations (Fig. 1). This is done by trimming back the soft tissue on both sides of the ear cartilage of one fragment and resecting a corresponding bit of cartilage in the other fragment to form a "groove" into which the other cartilage will fit.



A.

B.

Fig. 1.—A, Partial avulsion of left ear following truck accident; preoperative appearance. B, Postoperative appearance after conservative débridement and plastic repair by "tongue-and-groove" junction of wound edges.

When an ear is badly crushed, much of the covering soft tissue and cartilage may be destroyed. Here, one should avoid reckless destruction of good tissue and initial surgery should give questionably viable tags of skin a chance to recover. Continuous moist dressings of normal saline solution are applied and chemotherapy, with sulfadiazine and penicillin, is given as supportive treatment to minimize bacterial destruction of the injured tissues. Such an ear may heal with deformity, but structural preservation allows good late repair (Fig. 2).

One should be on the alert for damage to the middle ear and the initial injury or later complications should be treated promptly by appropriate measures. Associated skull fracture is common and leakage of cerebrospinal fluid from the ear should dictate a policy of noninterference, regardless of the condition of the pinna.

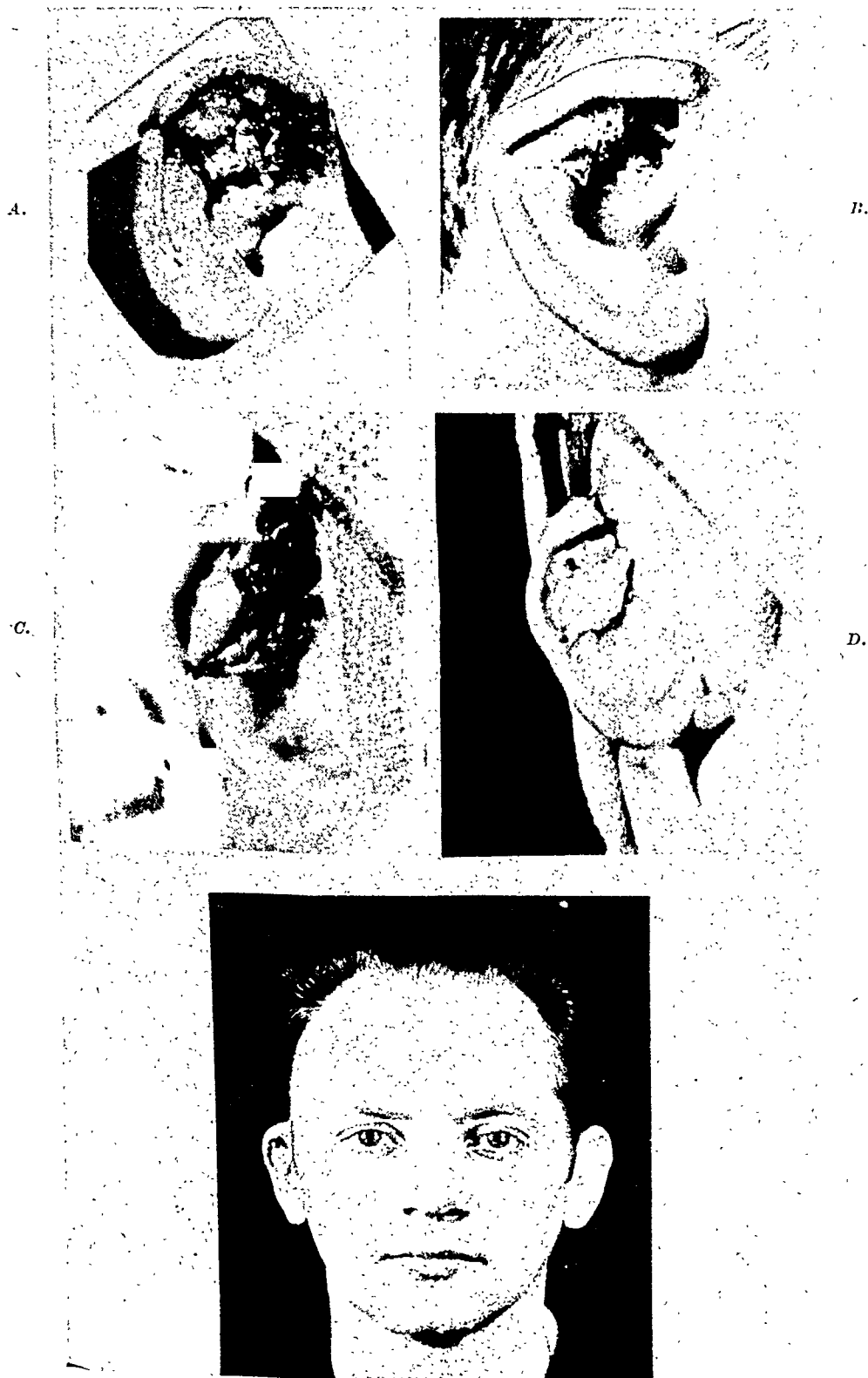


Fig. 2.—A, Appearance of crushed and lacerated ear on admission following injury by a cargo net. The bruised, blue tissues were covered with dirt, and cartilage was shredded. An associated cerebral concussion had occurred, but no skull fracture was present. B, Healed appearance following conservative débridement and normal saline solution dressings. C, All scar tissue excised and wound open. D, Skin loss replaced by full-thickness skin graft from behind other ear. E, Final result.

A.



B.



C.



D.



E.



F.



Fig. 3.—A and B, Appearance of ears, fourteen days following gasoline burn aboard motor launch. Initial pressure dressings have now been replaced by frequently changed normal saline dressings in preparation for grafting. C and D, Thick-split grafts have been applied and are now healed. Some contracture has occurred, however, and the ears have become slightly cup-shaped, protruding more than normal. E and F, Final appearance after plastic revision of the protruding ears.

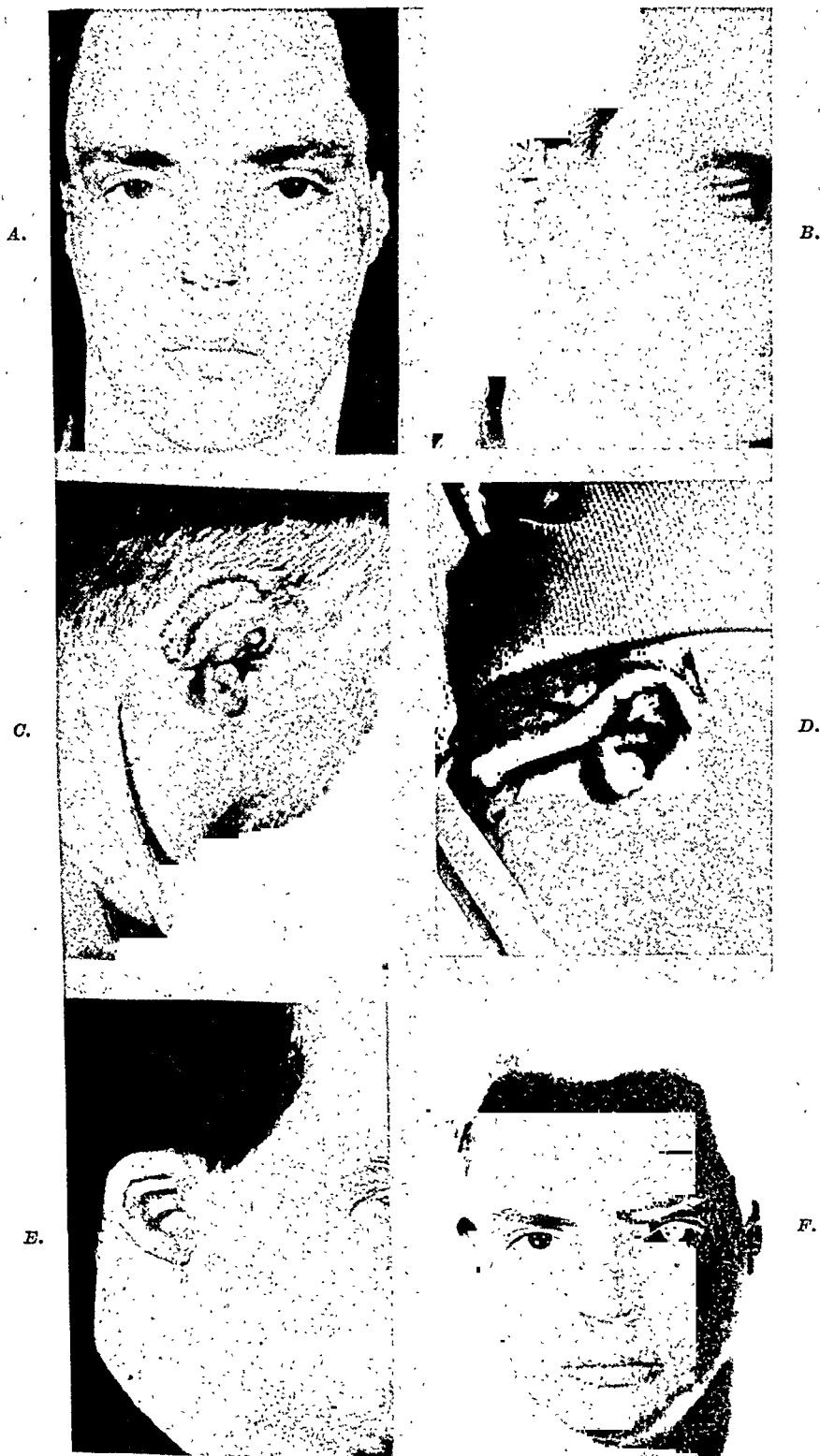


Fig. 4.—A and B, Subtotal loss of right ear following flash burn aboard torpedoed vessel. C, Retro-auricular flap has been swung forward and tubed pedicle flap formed on the neck. D, The tubed pedicle flap is now in place, reconstructing the helix; cartilaginous support is added later. E and F, Final result.



Fig. 5—A and B, Necrosis following radiotherapy to hemangioma of left ear. Severely ulcerating scar resulted. C and D, Retro-auricular flap has been applied following excision of all damaged tissue. E, A thick-split graft from the arm covers the defect behind the ear. F, Early end result at time patient returned to duty.

THERMAL OR CHEMICAL INJURY

Destruction of the external ear can occur from extremes of heat and cold, from electricity, and from the action of noxious chemicals. Although the latter two are less common, the familiar appearance of the ears of the burned aviator, tanker, or petroleum handler has become commonplace during this war. Extreme damage from frostbite is equally severe among exposed personnel.

Much of this thermal injury to the ear is so intensely destructive that no treatment can prevent deformity. If the injury is less severe, however, good care can conserve the surviving tissues. Nonadherent, fine-mesh gauze, impregnated with petrolatum or parawax, and mild pressure with carefully molded fluffed gauze should be used for the first few days. This prevents drying and further tissue necrosis. Thereafter, as soon as granulations appear the dressings are changed to fine-mesh gauze, wet with normal saline solution. These dressings are changed with sufficient frequency that all wound discharges are carried away and are not allowed to accumulate. The prompt application of free thick-split skin grafts will then prevent further contraction and give maximum preservation of tissues and normal appearance (Fig. 3).

In many cases extensive destruction of the pinna requires plastic surgical reconstruction. The usual methods of repair involve moving forward a flap of retro-auricular skin, with a subjacent thick-split graft, or the application of a cervical tubed pedicle flap of skin and subcutaneous tissue, or a combination of both of these procedures. Cartilaginous support, or metallic supporting wires or strips, are added at various stages in the procedure, according to the particular desires of the operator. The end results, although not normal, are usually quite acceptable (Fig. 4).

INFECTIONS AND TUMORS

Both pyogenic and granulomatous infectious processes can destroy the ear, but practically the only type with which we are concerned in this paper includes those infections which occur as a localized abscess or cellulitis following crushing wounds or burns. Systemic chemotherapy, with sulfadiazine and penicillin, is used to supplement local fomentations of warm saline solution. Early recognition and drainage of localized abscesses will prevent many of the contractures which follow infected wounds or burns of light severity. A number of these have been noted during World War II and their prompt recognition and treatment are urged.

Benign and malignant tumors are uncommon in the military age groups, but constant vigilance should be maintained for any suspicious lesions, particularly in the older, weather-beaten sailor. Their classification and treatment are beyond the scope of this paper, but one related traumatic agent, radiotherapy, may result in damage to the pinna that must be repaired (Fig. 5).

SUMMARY

In the surgical care of the injured external ear, all viable or potentially viable tissues should be conserved when the wound is débrided. Lacerations can be repaired primarily if there has been no appreciable loss of substance, or simple moist dressings may be applied to an injured ear which may require later reconstruction. Burned ears should be kept from drying and granulating surfaces grafted as soon as possible. Post-traumatic abscesses should be recognized and drained early.

HYPERTHYROIDISM WITH PROGRESSIVE EXOPHTHALMOS AND WITHOUT TACHYCARDIA

REPORT OF A CASE

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REPUBLIC OF PANAMA

(From the Santo Tomás and Amador Guerrero Hospitals)

WE ARE reporting an unusual case of hyperthyroidism which has come under our observation, and which presented the following peculiarities: (1) absence of tachycardia; (2) severe progressive ophthalmopathy which dominated the clinical picture; and (3) absence of thyroid enlargement. The patient was successfully operated upon, and sections of the removed thyroid gland were reported as typical of Graves' disease.

CASE REPORT

C. S., a 45-year-old, dark-skinned Panamanian laborer, was admitted to the Amador Guerrero Hospital (under the care of M. R.), May 1, 1944, with the chief complaint of loss of weight, nervousness, and exophthalmos. He had considered himself in good health until a few months previously, when he began to notice a tired feeling after moderate effort, loss of weight in spite of good appetite, and protrusion of his eyes. He claimed to have lost thirty-five pounds in the preceding three months, and complained of nervousness, insomnia, excessive perspiration, and occasional diarrhea. But what bothered him most was the condition of his eyes, which were protruding, and subject to periodical bouts of edema, redness, and lacrimation with severe local pain.

Physical Examination.—Examination showed an undernourished, well-built, middle-aged man, in no acute distress. Temperature was 98.4° F., blood pressure 130/70, pulse rate 80. The heart was not enlarged, nor otherwise abnormal; the thyroid was not palpable. A slight tremor of the extended hands and fingers was noticeable. His eyes had a staring expression due to exophthalmos and widening of the palpebral fissure, blinking was almost abolished, and the patient was unable to close his eyes because of the exophthalmos, which made it impossible for the eyelids to cover all of the protruding eyeballs. At this time no edema or inflammation was present in the eyelids or conjunctivae.

During the first week in the Amador Guerrero Hospital, his weight was 102 pounds, basal metabolic rate plus 97, and later plus 92. Kahn blood test was negative; urine, blood counts, and x-ray of the chest were reported as normal. Electrocardiogram showed a normal sinus rhythm, with a rate of 80 beats per minute. The only electrocardiographic abnormality that was reported was a striking deformity of the P waves in Leads I and II, consisting in high, narrow, and peaked deflections.

During the first two weeks the patient was placed on a high-caloric, high-vitamin diet, with extra doses of vitamin B complex and vitamin C. He lost three additional pounds under this regimen. He began to complain of severe discomfort in the eyes, and developed redness, lacrimation, and moderate edema of the eyelids. An ophthalmologist was called in consultation to rule out intraocular primary pathology. The conclusion was reached that the whole picture could fit in the diagnosis of severe exophthalmos from hyperthyroidism. He was then put under iodine therapy, and a striking improvement took place in his general condition: nervousness disappeared almost entirely, bowel movements diminished from four to five to only one each day, he gained six pounds, and basal metabolic rate fell to plus 47. But, at the same time, the condition of his eyes became definitely worse. The edema of the eyelids became conspicuous, chemosis of the bulbar conjunctiva appeared, and pain and lacrimation interfered constantly with his sense of well-being. At this point the surgical department of the Amador Hospital was consulted on the advisability of immediate thyroidectomy, since we felt that medical treatment would not control the ophthalmopathy which was interfering

with the patient's general condition, for constant pain and discomfort kept him restless and sleepless. No decision could be reached, and the patient continued under iodine medication, plus heavy sedation to control the pain in his eyes. The ophthalmopathy progressed unmercilessly until, June 20, a perforation of the left cornea developed, with loss of intra-ocular fluid. At this stage enucleation of the perforated eye was considered necessary, and the patient was transferred to the Santo Tomás Hospital.

Here evisceration of the left eye, and novocain block of the right stellate ganglion were performed, with temporary improvement in the condition of the remaining eye. His weight now was 106 pounds, basal metabolic weight plus 55, and electrocardiogram continued to show high and peaked P waves with normal sinus rhythm. Fasting blood sugar was 105, nonprotein nitrogen 29, blood cholesterol 126, blood calcium 11, blood Kahn negative, spinal fluid Kahn also negative. Urine was normal, and blood counts gave normal findings. Iodine medication was begun for the second time and he began to improve, gaining six pounds in weight, with a drop of the basal metabolic rate to plus 33. But here again doubts were expressed as to whether this patient really had hyperthyroidism, as most of the surgeons would not accept such a diagnosis with a pulse rate that never exceeded 90 per minute, and usually was between 60 and 80. Iodine therapy was accordingly stopped. In the next two weeks the patient lost six pounds, and the basal metabolic rate returned to plus 55, together with a definite exacerbation of the toxic symptoms. With this new evidence in favor of hyperthyroidism, iodine therapy was reinstituted and operation performed September 27, with the basal metabolic rate at plus 12, and weight at 117 pounds.



Fig. 1.



Fig. 2.

Fig. 1.—C. S., preoperative photograph taken in June, 1944, at Amador Guerrero Hospital.

Fig. 2.—C. S., photograph taken in December, 1944, three months postoperatively, at Santo Tomás Hospital, Panama.

He was transferred to the operating room under intravenous pentothal anesthesia, and operated upon under ethylene ether-oxygen anesthesia. Subtotal right and total left thyroidectomy was successfully performed (G. O. C.). The removed gland was sent to the laboratory, and the following report was received: The specimen consisted of two pieces of thyroid, one weighing 19 Gm. and measuring 6 by 2 by 4 cm., the other weighing 20 Gm. and measuring 6 by 3½ by 2½ cm. The tissues showed congestion. The cut surface did not show formation of adenoma. The tissue appeared homogeneous and had a pink color slightly deeper than normal. On microscopic examination all sections showed the same pathologic picture; old and fresh hemorrhages were found, as were a few wandering cells in the interstitial tissues.

In general the acini appeared normal, but there were small areas that showed disappearance of colloid and changes in the shape of the epithelial cells. Careful examination did not reveal malignant changes nor small adenomas. Anatomic diagnosis was hypertrophy of the thyroid gland with changes which could be considered typical for toxic goiter.

The postoperative course was uneventful, except for a slight bronchitis that cleared in a few days under sulfadiazine medication. Immediately on returning to the ward he was placed under iodine and thyroid extract therapy (1 gr. thyroid, three times daily).

From then on his basal metabolic rate has been kept within normal limits, the condition of the right eye has improved gradually, and at present the conjunctival edema has disappeared completely, and he is even able to close the remaining eye, as the exophthalmos has diminished greatly. He has gained over thirty pounds in weight, and feels in perfect condition. No signs or symptoms of myxedema have developed. The basal metabolic rate in the last three months has been kept between plus 14 (Nov. 7, 1944) and minus 9 (Jan. 14, 1945). Weight on Jan. 13 was 138 pounds.

COMMENTS

The presence of progressive exophthalmos with periorcular edema, chemosis of the conjunctiva, lacrimation, pain, and ulcerative keratitis, in the absence of tachycardia and of enlargement of the thyroid gland, made the case a difficult diagnostic problem for us. It might be assumed that nervousness, loss of weight, high basal metabolic rate, and gastrointestinal upsets could be due to his intense discomfort and mental strain brought about by the severe, progressive bilateral ophthalmopathy. The strongest evidence in favor of hyperthyroidism in this case was the observation that under iodine therapy all toxic symptoms decreased in intensity in spite of the little, or no, effect of this type of therapy upon the ophthalmopathy.

A similar case, in a 6-year-old Negro girl, has recently been reported by Haik,¹ with an extensive review of the literature on the subject of progressive exophthalmos in toxic disease of the thyroid gland. We feel that our case can be considered a typical example of Graves' disease of the ophthalmic type according to Means' classification.² In fact, our case presented the following characteristics:

1. Thyrotoxicosis was readily and repeatedly controlled by iodine medication.
2. The patient was a male.
3. Thyroid enlargement was not notable.
4. There was dissociation of thyrotoxicosis and ophthalmopathy, as general improvement of the toxic symptoms was often accompanied by an aggravation of the ophthalmopathy, and vice versa.
5. The more conspicuous ocular signs consisted of periorcular edema and chemosis of the conjunctiva, although in our case (as in Haik's case) the classical ocular signs of exophthalmos, lid lag, and lid retraction were also present.

When thyroidectomy was decided upon, our main problem was to avoid the progression of the exophthalmos in the remaining eye, as we had observed that each time the basal metabolic rate had been lowered, through iodine medication, an increase in the severity of the ophthalmopathy resulted. Furthermore, most writers have warned that in such cases thyroidectomy usually brings about very little relief of the exophthalmos, and may even aggravate it.

Following the theory that considers exophthalmos a product of excessive secretion of thyrotropic hormone by the anterior lobe of the pituitary gland, and considers that this effect of the thyrotropic hormone is counteracted by the presence of thyroid hormone,³ and knowing that the feeding of thyroid extract after thyroidectomy with the purpose of controlling the progression of the exophthalmos had already been tried,⁴ we gave thyroid extract to the patient,

checking the basal metabolic rate at weekly intervals. In this case, this measure seems to have been successful, as in the three months that followed the operation, the right eye returned to almost normal condition.

Another interesting observation in this case was the peculiar high peaked P waves of the electrocardiogram. It has been common experience at the Santo Tomás Hospital to notice high P waves together with sinus tachycardia in cases of hyperthyroidism. This is the first instance in which the P waves were high and peaked with a normal sinus rhythm of 80 per minute. After the operation the P waves returned to a more normal configuration.

SUMMARY

We have presented a case of hyperthyroidism of the ophthalmic type. Enucleation of one eye (left) was necessary, because of perforation of the cornea following ulcerative keratitis. Thyroidectomy followed by thyroid administration seems to have given satisfactory results in the control of the ophthalmopathy.

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LOSS OF SCROTAL INTEGUMENT

A SIMPLE METHOD OF REPAIR

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THE primary purpose of this communication is to call attention to a simple method of stretching remnants of scrotal integument to an extent which may obviate the necessity of using more complicated plastic-flap operations.

Secondarily, a short résumé of a case history of scrotal gangrene following an operation for recurrent left inguinal hernia, in which the described method was used, will be presented.

A search of the literature on gangrene of the scrotum has failed to reveal a report of this condition following herniorrhaphy. There is no need here to discuss the general subject of scrotal gangrene, it being ably covered in numerous articles in general surgical and urological contributions.

The development of the gangrene in this instance followed a typical course, the cause, however, being evident rather than remote or unknown as is often the case.

CASE REPORT

F. K., a 44-year-old man, had an herniorrhaphy in May, 1937, for a direct, left inguinal hernia. There was recurrence one year later and a second operation was done. Three ten-inch strips were taken from the left fascia lata. All were used in making basket-weave repair. At the end of the first postoperative day, temperature of the patient was 101° F. Sulfanilamide was begun, 10 gr. (0.650) every four hours. There was a small amount

of dark red drainage with white flecks from the wound. A culture was taken. Marked edema of scrotum and penis with ecchymotic discoloration was present. No edema was noted twelve hours before.

From this point on, a typical course of scrotal gangrene ensued, of the type described by Hinman.* The skin became reddened, tense, and glossy, and hot and tender. It then began to "sweat," becoming greasy and covered with an exudate, and a moist desquamation began. Within three days, sloughing scrotal integument was clipped away. The process extended until only a cuff of scrotum approximately one inch in length remained, a bit longer posteriorly. The testes and spermatic cords were bare but not involved in the infection. Two organisms were found in the culture; Beta hemolytic streptococcus and hemolytic *Staphylococcus aureus*.

At this time sloughs of fascial sutures were picked from the hernia wound. The herniotomy wound was irrigated with normal saline solution twice daily. The solution poured out over the exposed scrotal contents. The latter were also irrigated twice daily and then covered with petrolatum gauze. The testes were supported on a Bellevue bridge.

For eighteen days following the loss of scrotum, the upper wound drained in lessening amounts with strips of fascia lata coming away at various times. The wound closed on the twenty-first day. From then on the temperature remained normal, having ranged daily from 99 to 101° F. until this time. In the meantime, healthy granulation tissue had covered the testes and spermatic cords, the edge of the remaining scrotal skin becoming incorporated in this granulation tissue. The sulfanilamide had been discontinued after four days, since the patient felt that it nauseated him. (This was in 1938.)



Fig. 1.



Fig. 2.

The personal equation in relation to the patient had much to do with the decision on the method of repair which was finally utilized. Surgeons will appreciate the mental agony which accompanies a complication such as developed in this case. The literature at that time, as today, proposed one of several methods of repair, all of which would no doubt have sufficed but which did not seem to fit the problem.

Undermining the contiguous areas of skin, including that of the thigh, seemed too dangerous from the standpoint of lighting up a latent infection. Waiting for epithelial outgrowth from scrotal remnant would have unduly prolonged an already stormy recovery, and there was little evidence that this would occur. Furthermore, the latter method of repair would leave a contracting cicatrix which, while covering the testes, would not be the best type of integument. Again, there was not enough scrotal skin to allow approximation of the edges, even had they been freed and undermined. Certainly, if possible, the patient was to be saved the nuisance of an operation requiring the use of plastic flaps from the insides of the thighs, which had been thought of and suggested as the safest procedure.

*Hinman, Frank: The Principles and Practice of Urology, Philadelphia, 1935, W. B. Saunders Company.

At this point, recalling the enormous extent to which scrotal skin with its dartos muscle becomes attenuated in accommodating large hernias, the thought occurred that some method of stretching the skin might serve the purpose. This was accomplished in the following simple manner.

Two strips of adhesive plaster were cut to the width of the scrotal skin remaining on either side, at the root of the penis. Their length was such that the strips could be brought down and, with some tension, fixed to the inner sides of the thighs, each strip being brought to the side opposite its upper end. Thus it was found possible to keep enough tension on the scrotal remnant to stretch it gradually yet not disturb the patient.

The edges of the scrotal skin remained in their fixed position but the parts above gradually came down over these edges. The adhesive was changed when it softened in its upper portion, and the stretching was increased by placing straps lower on the thighs each time. This was done daily, sometimes every second day. Looking back, it was probably not necessary to continue this stretching for three weeks, but the progress was so remarkable that it became apparent that an almost normal scrotum was in the process of formation. When the skin had stretched to the point at which it was considered sufficient, the edges were freshened and the well-stretched integument sutured over the exposed contents which at this time were completely covered by healthy granulation tissue.

It was forty days after the first slough came away that the skin edges of the now-stretched scrotum were freed from the granulation tissue. The latter was left intact. Oozing was controlled by hot saline solution packs. The freshened skin edges were then approximated by a running suture of alloy steel wire, the ends of which were twisted together over a gauze dressing. Healing was per primam, the patient leaving the hospital seven days later; the wire was removed at the end of two weeks.

Five years later, the scrotum is small but perfectly normal in appearance and action. There has, strangely enough, been no recurrence of the hernia.

SUMMARY

1. A simple method of repair of the scrotum is presented. It may be tried whenever there is enough remnant of scrotal integument to which adhesive plaster (or other means which would produce tension) may be applied.

2. A case of fulminating scrotal gangrene following a fascia-lata-strip repair of recurrent/inguinal hernia is cited.

3. The method might well be tried in war wounds of the scrotum. It seems that patients might be spared the application of more extensive plastic procedures.

My associate Lieutenant Colonel Floyd R. Parker, Medical Corps, Army of the United States, carried out the meticulous aftercare in the case and deserves a good share of the credit for the final outcome.

Book Reviews

Care of Neurosurgical Patient. By Ernest Sachs, M.D., St. Louis, 1945. The C. V. Mosby Company.

The author has written, very interestingly, a most instructive text. The treatment of the neurosurgical patient is concisely but thoroughly considered. Beginning with the preliminary examination, the treatment of the patient is followed through the preoperative care, the operative technique, and the postoperative care. On pertinent controversial points such as diagnostic measures and surgical approaches, Sachs reviews the methods in question. He then points out very adequately why his recommendations are the more sound.

The many and excellent illustrations add to the value of the text.

Announcement

Due to conditions beyond the control of the editors and publishers, several issues of the JOURNAL are printed on an inferior grade of paper. Just as soon as the standard good grade of paper is available, its use will be resumed.

SURGERY

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Original Communications

AN EXPERIMENTAL EVALUATION OF SULFASUXIDINE AND SULFATHALIDINE IN SURGERY OF THE COLON

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SUCCINYLSULFATHIAZOLE (Sulfasuxidine) was introduced as an intestinal antiseptic by Poth and Knotts^{1, 2} in 1941, and phthalylsulfathiazole (Sulfathalidine) was similarly introduced in 1943 by Poth and Ross.^{3, 4} These drugs were shown to be poorly absorbed from the gastrointestinal tract and to possess antibacterial activity sufficient to alter the bacterial flora affecting both the aerobic and anaerobic organisms. The clinical usefulness of these poorly absorbed sulfonamides as adjuvants in surgery of the colon has been demonstrated repeatedly as reviewed by Poth.^{5, 6}

The oral administration of phthalylsulfathiazole (sulfathalidine) and succinylsulfathiazole (sulfasuxidine) was shown originally by Poth and Knotts,^{1, 2} Poth,⁷ Poth, Knotts, Lee, and Inui,⁸ Zintel, Lockwood, and Snyder,⁹ and Poth and Ross¹⁰ to alter significantly both the aerobic and anaerobic bacterial flora of the gastrointestinal tract. The toxicity of these drugs is relatively low,⁶ however, as occasionally occurs with all sulfonamides, any particular patient may be sensitive to the drug, requiring that all sulfonamides must be administered with caution.

The effect of the alteration of the bacterial flora by the oral administration of these two drugs to dogs on the results of crushing trauma and of enterostomy involving the descending colon was studied by the following experimental procedure.

PROCEDURE

Mongrel dogs were placed in individual cages and fed boiled horse meat six times daily at four-hour intervals¹¹ for three days before operation. The quantity of meat fed was such that the animals were always sufficiently hungry to consume all of their food immediately. When a drug was administered, it was mixed with the meat.

Fecal specimens were taken directly from the rectum by aspiration into a sterile glass tube the day prior to operation and were cultured for coliform organisms on desoxycholate media as poured plates. The counts were made after incubation at 37° C. for forty-eight hours. Ordinarily, only the number

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of coliform organisms present was determined, and the alteration in these counts was taken to indicate the degree of alteration of the bacterial flora.

All operations were performed under ether anesthesia with observance of the usual surgical precautions. Immediately after operation, the animal was placed upon preoperative rations, which were available as soon as he cared to eat.

Crushing Injury of Ileum and Descending Colon.—Six animals were separated into three groups of (1) three control animals on standard meat diet, (2) one animal treated with 1.0 Gm. of succinylsulfathiazole per kilogram of body weight added to standard meat diet, and (3) two animals treated with 0.25 Gm. of phthalylsulfathiazole per kilogram of body weight added to standard meat diet.

In each instance a large Payr clamp, having a jaw 1.0 cm. in width, was applied across the bowel at the mid-section of the descending colon and across the ileum at a level 10 cm. proximal to the termination of the small antimesenteric artery extending cephalad from the ileocecal region. This clamp was left in place for two minutes and crushed the viscus so that only the submucosa remained intact. These animals all survived and were sacrificed after five days. The omentum was adherent at all crushed areas. The adjacent omentum and mesentery were extensively swollen and edematous in the case of the control animals, while only minimal swelling and edema were present in the drug-treated animals. Upon stripping away the adherent omentum, multiple small abscesses were revealed in the controls, whereas there was no evidence of infection when the animal had received either of the drugs. The following specimens were taken in each instance: a segment of bowel, 2.5 cm. in length, which included the crushed area, was excised and a control portion of bowel of equal length was taken approximately 10 cm. cephalad to the first. These specimens were wiped clean, weighed, and dried to constant weight by lyophilization. The water content is given in Table I. Somewhat less edema occurred when either sulfasuxidine or sulfathalidine had been administered prior to the trauma.

Aseptic Enteroenterostomy of Descending Colon.—Six animals were divided into three groups of two each. The animals in one group were placed on the standard meat diet, those in the second group received 1.0 Gm. daily of succinylsulfathiazole per kilogram of body weight in the standard diet, and those in the third group received 0.25 Gm. daily of phthalylsulfathiazole per kilogram of body weight in the standard diet. After ten days an aseptic end-to-end anastomosis was performed using the Poth intestinal clamp.¹² A continuous inner row of 2-0 chromic catgut was placed in a manner to turn in a minimum of bowel, reinforced with a row of interrupted Cushing sutures of No. 3 twist silk. These animals all survived and were sacrificed after five days. The omen-

TABLE I. LOSS OF WATER ON LYOPHILIZATION OF SEGMENTS OF TRANSVERSE COLON AND ILEUM FIVE DAYS FOLLOWING CRUSHING TRAUMA IN TREATED AND UNTREATED ANIMALS

TREATMENT RECEIVED PRECEDING TRAUMA	WATER CONTENT IN PER CENT			
	TRANSVERSE COLON		ILEUM	
	CRUSHED SEGMENT	CONTROL SEGMENT	CRUSHED SEGMENT	CONTROL SEGMENT
Sulfasuxidine	78.09	75.45	75.74	78.49
Sulfathalidine	79.31	78.19	80.93	76.81
Sulfathalidine	79.27	78.68	78.45	77.92
No drug	79.16	77.09	78.48	78.52
No drug	79.51	77.46	79.45	76.03
No drug	79.75	77.58	78.94	77.46

tum was adherent at the site of suture and was considerably more swollen and edematous in the controls than in the animals in which therapy had been employed. Otherwise, there was no significant difference. No microscopic studies were done.

End-to-End Anastomosis of Descending Colon by an Open Technique.—Since examination of the gross specimens obtained following the aseptic technique showed little difference between treated and untreated animals, an open technique accompanied by considerable soiling was studied.

Seventeen animals were divided into three groups: the first group consisted of seven animals placed on the standard meat diet; a second group, five animals given 1.0 Gm. daily of succinylsulfathiazole per kilogram of body weight in the standard diet; and a third group, five animals given 0.25 Gm. daily of phthalylsulfathiazole per kilogram of body weight in the standard diet.

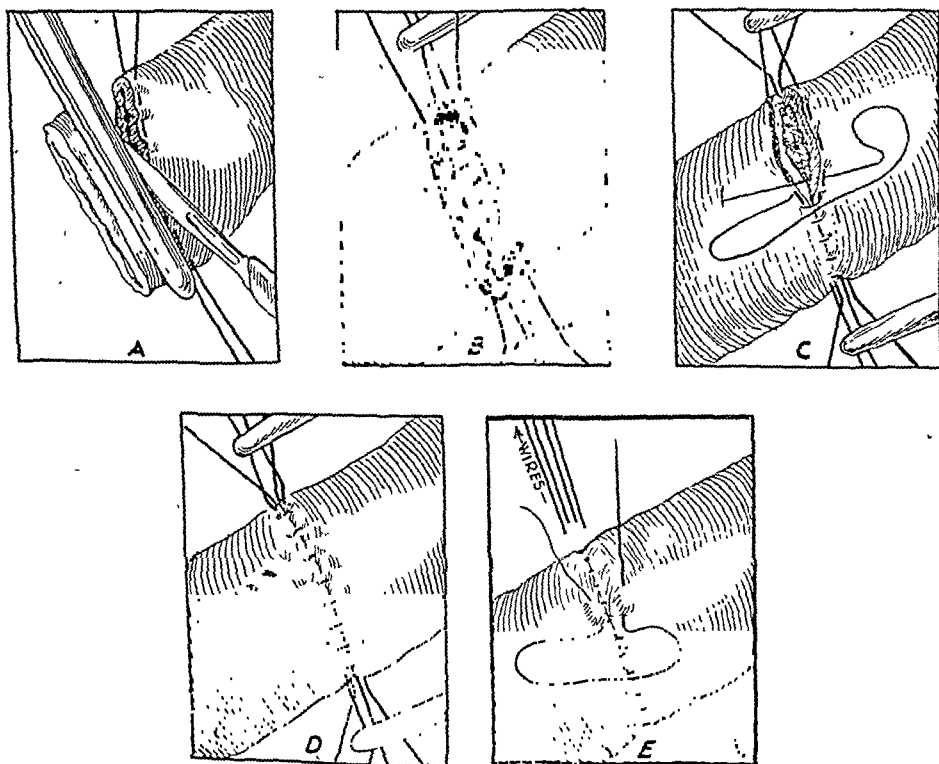


Fig. 1.—Open anastomosis of bowel. A, Fine stainless steel wires are inserted through the full thickness of the bowel wall to prevent retraction of the submucosa and muscularis, and eversion of the submucosa. By this method of fixation a more accurate and reproducible technique is realized. B and C, The inner continuous row of 000 chromic catgut is placed to include the fixation wires and invert the wall of the bowel. D, The fixation wires will be cut short on one end and withdrawn. E, The fixation wires are withdrawn, and the second row consisting of interrupted fine black silk sutures is introduced to complete the anastomosis.

In an attempt to find a satisfactory procedure for testing the value of the drugs in the preoperative preparation, an open technique giving a 50 per cent operative mortality was sought. The use of the technique illustrated in Fig. 1 resulted in the death of three out of seven of the control animals and in walled-off perforations at the suture line in the four animals which survived. When this same procedure was used on the animals in the second and third groups, which had been prepared with succinyl- and phthalylsulfathiazole, there were no deaths. No attempt was made to occlude the lumen of the bowel segments during suture, and extensive fecal contamination occurred regularly. All surviving animals were sacrificed after five days. The four control animals

which survived and were sacrificed on the fifth postoperative day showed massive, swollen, edematous omental adhesions surrounding gross perforations at the line of suture. The results obtained on the two series of drug-treated animals were practically identical. The suture lines were covered by adherent omentum which showed a minimum of swelling and edema. When the omentum was separated, two small stitch abscesses were revealed. There was no evidence of leakage in any instance.

Specimens were taken to include about 1.0 cm. of bowel on either side of the line of suture. A small section of the specimen was removed for microscopic study. The remainder of the specimen was dried to constant weight by lyophilization and the water content was compared to that of an adjoining segment of the bowel similarly treated (see Table II).

TABLE II. THE RESULTS OF OPEN ANASTOMOSIS OF THE DESCENDING COLON OF THE DOG FOLLOWING THE PROCEDURE ILLUSTRATED IN FIG. 1, IN TREATED AND UNTREATED ANIMALS

TREATMENT	PER CENT WATER IN SPECIMEN	PER CENT WATER IN CONTROL TISSUE	PER CENT WATER DIFF- ERENCE	CONDITION OF ANASTOMOSIS
Sulfasuxidine	75.85	75.00	+0.85	Intact, stitch abscess
Sulfasuxidine	79.71	79.30	+0.41	Intact, slight edema
Sulfasuxidine	76.69	76.12	+0.57	Intact, slight edema
Sulfasuxidine	72.03	76.22	-4.19	Intact, slight edema
Sulfasuxidine	75.10	76.29	-1.19	Intact, slight edema
Sulfathalidine	73.00	74.17	-1.17	Intact, slight edema
Sulfathalidine	75.30	74.60	+0.70	Intact, slight edema
Sulfathalidine	78.45	75.62	+2.83	Intact, stitch abscess
Sulfathalidine	76.27	78.40	+2.13	Intact, slight edema
Sulfathalidine	77.47	78.00	-0.53	Intact, slight edema
No drug	77.0	74.0	+3.0	Walled-off perforation
No drug	74.0	76.0	-2.0	Walled-off perforation
No drug	80.0	78.0	+2.0	Ruptured, dead 48 hr. P.O.
No drug				Ruptured, dead 48 hr. P.O.
No drug				Ruptured, dead 24 hr. P.O.
No drug	78.83	78.58	-0.25	Perforation, peritonitis
No drug	82.80			Walled-off perforation

The operations were performed in groups of three (one animal from each series) by the same operator (E. J. P.), on the same day, without his knowing specifically to which series any one animal belonged. The condition of the bowel and its contents, however, allowed the operator to differentiate immediately between the treated and untreated animals. Although it was not possible to prevent the surgeon from knowing whether or not the animal had received drug therapy preoperatively, every effort was made to perform identical operative procedures.

Microscopic study* of specimens taken through the line of suture revealed a considerable difference in the healing process between the control animals and those treated with either of the drugs. The specimens taken from the control animals showed an acute inflammatory reaction. There was little or no evidence of granulation tissue being formed. The serosal surface was covered with an exudate consisting of fibrin and polymorphonuclear leucocytes. There was marked hyperemia of all vessels with extensive edema.

The specimens taken from the animals which had received either sulfasuxidine or sulfathalidine showed a subacute inflammatory reaction. Along both edges of the suture line there was active proliferation of fibroblasts and newly formed capillaries. The surface was covered by a layer of pink-staining material made up of old fibrin, polymorphonuclear leucocytes in varying stages

*These studies were made by Dr. Paul Brindley, Professor of Pathology, University of Texas Medical Branch, Galveston, Texas.

of disintegration, and lymphocytes. The adjoining tissues were infiltrated with a moderate number of polymorphonuclear leucocytes, lymphocytes, plasma cells, and large mononuclear cells. The serosal layer was infiltrated with numerous lymphocytes, plasma cells, large mononuclear cells, and fibroblasts. Only a few polymorphonuclear cells were present in this layer. The tissue showed only a moderate amount of edema. In summary, the bowel of the control animals showed considerable edema, necrosis, and an acute inflammatory reaction with little or no evidence of healing, whereas the corresponding tissues from the drug-treated animals showed subsidence of inflammation with well-advanced healing and repair.

DISCUSSION

These controlled experiments show conclusively that both sulfasuxidine and sulfathalidine are valuable adjuvants in surgery upon the colon of the dog. The reaction, as revealed by the amount of edema of the omentum adherent to the line of suture, is significantly less when the bacterial flora is modified by the administration of the drugs. The most clear-cut evidence of the value of these drugs is revealed by the results which followed the method of open anastomosis, wherein no effort was made to prevent fecal soiling of the operative field. Even though the degree of spillage was much greater following the administration of sulfasuxidine because of the semifluid nature of the contents of the bowel, there was a striking difference in the operative mortality and morbidity. Forty-three per cent of the control animals died of generalized peritonitis due to disruption of the line of suture. One hundred per cent of the control animals showed gross leakage at the line of suture. These observations are in contradistinction to absence of death and lack of gross leakage through the suture line when the animals had received sulfasuxidine and sulfathalidine. Furthermore, in the control experiments there was acute inflammation and little evidence of healing and repair by the fifth postoperative day. Following drug therapy, the inflammation had subsided and the tissues had undergone orderly repair and healing.

CONCLUSION

This study shows sulfasuxidine and sulfathalidine to be valuable adjuvants in surgery on the colon of the dog. The indications are that the so-called aseptic methods of anastomosis should be used whenever possible, but it is evident that an open technique may be undertaken with a considerably increased degree of safety. These observations support the satisfactory results obtained when man is treated in a similar manner.

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SURGERY OF THE COLON IN THE FORWARD BATTLE AREA

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WHENEVER colon wounds among battle casualties are mentioned, the subject is usually dismissed with the dictum, "Exteriorize all colon wounds." But, the question is often asked, "How?" Uncertainty may exist as to how to handle a particular colon wound. Should one always construct a double-barreled, spur colostomy? At the base hospitals some surgeons have felt that all colostomies should be closed by crushing a spur. Colon injuries, as a group, carry a high mortality and are among the most serious injuries that one encounters. However, the management of them and the indications for performing different types of colostomies seem clear cut; confusion over these points need not exist.

Trauma to the colon may be grouped as follows: (1) Perforations of the antemesenteric portion up to one-half of the diameter of the segment; (2) perforations of the mesenteric border and perforations of the antemesenteric border larger than one-half the diameter; (3) severely torn segments necessitating resection of a segment; (4) complete transections; (5) injuries to the mesentery producing nonviable segments; (6) the first five groups occurring in the rectosigmoid just above the pelvic floor; (7) The same five groups occurring in the rectum, between the pelvic peritoneum and the anus; (8) injuries necessitating right colectomy or cecectomy. This last group (8) will be discussed separately, as it involves the handling of ileal contents.

All exteriorizations of the colon, that is, all colostomies, should be planned and constructed, bearing in mind the simplest and most feasible method of closure at a later date. With this point in mind it becomes evident that a double-barreled spur colostomy need not always be performed, nor should one think that all colostomies should be closed by clamp-crushing of a spur. There are two types of colostomies to employ, each being indicated in specific cases. They are (1) the tangential or simple, no spur, loop colostomy and (2) the sutured, long, double-barreled, spur colostomy. Into Type 1 colostomy (the simple, no-spur loop type) falls Group 1 of the traumatic injuries listed. Why? Because these antemesenteric perforations, less than one-half of the diameter of the gut in extent, are preferably and more simply closed, at a later date, by freeing the gut from the abdominal wall and simply closing the perforation with a continuous "0" chronic catgut suture in the fashion of Connell reinforcing this row with inter-

rupted Lembert sutures of silk and dropping the segment beneath the fascia of the abdominal wall but exterior to the peritoneum. If the peritoneum is thin or cannot be dissected free from the fascia of the abdominal wall, then the sutured gut can be dropped back into the free peritoneal cavity with impunity. It is taken for granted that, when one elects to close a colostomy, he will undertake it only on a prepared colon; prepared mechanically with laxatives and irrigations with or without the use of succinyl-sulfathiazole, preferably by a combination of both. This type of colostomy is indicated also as a proximal colostomy in treating injuries in Group 6 which involve the rectosigmoid portion of the colon. The damaged portion of bowel at this level cannot be mobilized enough to be exteriorized. And, again, this simple, no-spur, loop colostomy is indicated in injuries of the rectum where a proximal colostomy is always necessary. Some think that a no-spur, loop colostomy does not sufficiently defunctionate the distal segment in order to employ it in Groups 6 and 7. After talking to base surgeons about this point and after seeing some of the patients with examples of insufficient defunctioning of the distal segment, I believe that, in part, this objection is based on faulty technique in performing the loop colostomy rather than on the principle of the use of this type of colostomy. One of the most frequently encountered complications of colostomies has been that of retraction. This retraction is due to improper mobilization of the segment. A fecal fistula results and, of course, insufficient defunctioning of the distal segment also results. In the majority of injuries falling in Groups 6 and 7, a properly performed no-spur, loop colostomy is quite sufficient. In exceptionally severe injuries of the rectum in which it is obvious that diversion of the fecal stream will be necessary for a long time, complete transection of the proximal colon with suturing of a long double-barreled spur colostomy to be crushed later with a clamp is preferable. A no-spur, loop colostomy brought out through a grid-iron incision with a small but adequate incision placed on the antemesenteric border of the exteriorized loop is a simple, quickly performed, and easily closed type of colostomy.

Conversely, trauma in Groups 2, 3, 4, and 5 should be treated by construction of a double-barreled spur colostomy. Thereby, the stage is set for early, easy closure by crushing the spur with a clamp. If these injuries are treated only by exteriorizing without constructing a long, double-barreled, spur colostomy, the re-establishment of continuity of the gastrointestinal tract at a later date will develop into a complicated procedure.

The surgeon in the forward area should consider the problems confronting the surgeon in the base area when he constructs a colostomy, and have in mind, at the time, making the closure as simple as possible. The proper time to lay the groundwork for closing a colostomy is when that colostomy is first made. The surgeon in the forward area should indicate clearly on the record the type of colostomy he made and what type of closure he had in mind when making it. The surgeon in the base should heed this and perform a closure accordingly. It is simply a matter of cooperation between the two surgeons.

Trauma in Group 6 will, of course, need, as previously stated, a proximal no-spur, loop colostomy. In addition, since exteriorization of the perforation is anatomically impossible at this level, a simple antemesenteric perforation needs only to be closed. Large tears, etc., should be treated by resection. In this area a lateral anastomosis will usually be impossible, and an end-to-end

anastomosis will be the one of choice. This region, then, namely the rectosigmoid just above the pelvic peritoneum, is the only place that resection of the colon with anastomosis is advisable. To repeat for the sake of emphasis, if the area cannot be exteriorized a proximal colostomy is mandatory and the perforations should be closed or resected and anastomosed.

In regard to Group 7 (injuries of the rectum), a coccygectomy, through a horseshoe incision, is sometimes necessary for adequate exposure of the injured area for drainage. However, coccygectomy is not advised as a routine procedure because of the sequela of osteomyelitis of the sacrum which is sometimes encountered. In most instances adequate drainage has been obtained without coccygectomy. These lesions obviously should have in addition to posterior drainage a proximal colostomy. As just stated, in most instances one of the simple no-spur, loop type is sufficient. If feasible, closure of the perforation is desirable. If this breaks down nothing is lost. If one be confronted with a large torn segment it would not be wise to attempt an end-to-end anastomosis at the time of the initial operation. One should wait until a later date at the base to attempt re-establishment of the continuity of the gastrointestinal tract. At this elective time at the base, all of the available length of intestine can be utilized and one will have a better chance for primary healing. Also, to secure enough length of bowel in this limited fixed area to perform an anastomosis if, for instance, a segment of any length be lost, it would be necessary to incise the pelvic peritoneum, pull down sufficient redundant rectosigmoid for anastomosis with the shorter fixed portion near the anus, and to close the pelvic peritoneum around the displaced rectosigmoid at a level higher than that at which it was originally attached. Regarding the initial surgery, in cases of extensive damage to the rectum, a point to remember in performing the proximal colostomy in the redundant rectosigmoid is to leave sufficient length distal to the colostomy for a later pull-down operation from below as described.

“When should one open a colostomy?” One need have no fear of peritonitis developing from retrograde soiling through the opening in the abdominal wall. If a proximal colostomy is being constructed for an unexteriorizable injury to the rectosigmoid or to divert the fecal stream from a perforated rectum, the colostomy should be opened at the time at which it is made; that is, on the operating table. One is defeating the purpose of the operation if he waits twenty-four to forty-eight hours before opening the colostomy. During the period of delay the closed perforation or resection of the rectosigmoid or the closed perforation or open laceration of the rectum will be bathed in feces. If a perforation in the mobilizable portions of the colon is exteriorized it should be left open; there is no need to place a clamp on it for twenty-four to forty-eight hours. If the exteriorized perforation is a very small one, one may wish to close it, leaving it exteriorized. If primary healing occurs, so much the better. If the suture line breaks down no harm is done. It is well to empty mechanically as soon after operation as possible all feces from the rectosigmoid or rectum.

In constructing a spur or loop colostomy the colon should be so mobilized that the colostomy lies free and quite loosely on the abdominal wall. All tension, tacking sutures to hold it to the abdominal wall, and dependence on clamps to prevent retraction into the peritoneal cavity, should be avoided. This is a most important point.

The length of a long, double-barreled, spur colostomy should be at least six inches, and the two long separate continuous rows of catgut sutures, about three-

fourth inch apart, should be placed on the antemesenteric borders of the two loops. These rows are best placed along two of the longitudinal fascial bands on the colon. Notes should be made of this so that when a clamp is placed for crushing the spur, it can be placed between these two rows of sutures. This will prevent any herniation of small bowel between the loops, any danger of clamping the mesentery, and will give an opening between the two loops that lies between two lines of sutures. A portion of these two lines of sutures will lie below the level of the peritoneum. For this reason, it is of the utmost importance to place the sutures not so deep as to run the risk of entering the lumen of the gut. If this precaution is not taken, there may be a late perforation due to infection along the suture line.

One point that should be emphasized in dealing with the colon is that of mobilization. The entire right colon, both flexures, and a portion of the rectosigmoid have about one-half of their diameter lying retroperitoneally. In explorations and in relief of tension on colostomies, the simple procedure of mobilizing these areas should be kept in mind. The lateral attachments of these portions of the colon are avascular, the mesentery coming in from the medial aspect, and they can be incised with impunity, displacing the colon medially.

Injuries of the right colon from the ileocecal junction distally, necessitating removal of the cecum and any portion of the right colon, are a problem because of the difficulty in dealing with the transected end of the terminal ileum. The open end of the ileum is, of course, a problem because of the erosive action of its contents if allowed to drain out into the abdominal wall. There are four ways of handling this problem. First, a primary anastomosis may be performed between the terminal ileum and the cut end of the transverse colon (end-to-side ileotransverse colostomy), the blind end of the colon being turned in by suture. Second, an end-to-side primary anastomosis may be performed, bringing out, through a stab wound, as a safety valve, the blind open end of the colon. Third, a lateral anastomosis may be performed between ileum and colon, bringing out both ends (ileum and colon) distal to the anastomosis as a double-barreled, spur colostomy. Fourth, ileum and colon may be exteriorized as a long, sutured, double-barreled ileocolostomy constructed for the purpose of early crushing of the spur with a clamp. The first three procedures are objectionable since they necessitate a primary anastomosis in an unprepared colon. This is too dangerous a procedure to employ. The fourth alternative is the one which has been used with good results. Early crushing of the spur back at the base hospital within two to three weeks, or earlier crushing at the front, preferably the former, will prevent any irreparable skin erosion. Postoperative care consisting of vitamins and correction of dietary deficiencies and restoration of blood chemistry to normal levels will play a large part in such treatment.

All exteriorizations should be brought out through separate stab wounds and not through the upper or lower poles of an exploratory incision. Often it has been convenient to bring a colostomy out through a débrided wound of entrance or exit, but this is avoided if possible.

There is a place for tube cecostomies in handling single perforations of the cecum. However, in general, it is preferable to exteriorize such wounds. The evacuation of the patient and the change of hands that he unavoidably falls into may produce periods of time when proper attention cannot be paid to the tube.

A tube may be of advantage in diverting the stream of ileal contents in an ileocolostomy, or may be used in a colostomy, but its period of usefulness is short as leakage occurs around the tube. In practice we have not employed tubes for such purposes.

Questionably viable areas of colon due to damaged mesentery or to trauma to the wall of the gut proper should be exteriorized.

The management of war wounds of the colon differs materially from the management of lesions of the colon generally encountered in civilian practice. The excellent results obtained in civilian practice by the performance of primary anastomosis on the properly prepared colon permitted the immediate replacement of the anastomosed portion into the general peritoneal cavity. In dealing with emergency war surgery it is felt that all colon injuries should be exteriorized and no primary anastomosis is warranted.

The opinions herein stated are based on two years' experience in performing initial, first priority surgery as the operating surgeon on a general surgical team of an auxiliary surgical group employed in several of the most forward hospitals set up next to a division clearing station. This experience was gained with the Seventh Army in the Sicilian Campaign and with the Fifth Army in the Italian Campaign.

CASE REPORTS

The following eight cases will illustrate the different types of colostomies and the conditions in which each was indicated.

Five cases of trauma to the right colon, including the cecum were of sufficient extent to require removal of cecum, ascending colon, and hepatic flexure. Each of these was handled by suturing a long, two row double-barreled, spur ileotransverse colostomy bringing the ileocolostomy out through a separate incision as described. Three of these patients (Cases 1, 2, and 3) died in the immediate postoperative course due to the severity of their wounds. This type of ileocolostomy, in itself, obviously did not contribute to death. One patient (Case 4) had an uncomplicated postoperative course. The ileostomy began functioning well on the third postoperative day. The patient was evacuated to a base section on the fifteenth postoperative day. On this day there was a small amount of redness beginning to appear around the ileostomy opening. Follow-up on this case revealed that the spur was satisfactorily crushed during the fourth week and that no serious erosion of the abdominal wall had occurred.

One patient (Case 5) was operated upon at a time recent to that of this writing, and follow-up data on the case have, as yet, not been obtained. Due to the rapidity with which our battle lines were moving forward at the time, it was necessary to leave this patient on the third day. Although obviously suffering from peritonitis, the patient seemed to be withstanding the infection and I assume that he survived.

Case 6 illustrates trauma to the splenic flexure of such extent that it was necessary to resect this portion of the colon and construct a long, sutured double-barreled, spur colostomy. This case also is exemplary of that group of injuries occurring in the rectosigmoid so low down that they cannot be exteriorized.

Cases 7 and 8 are examples of injuries of the colon that required only simple exteriorization of the perforation as a no-spur loop colostomy.

CASE 1.—A soldier was injured 2:00 A.M., Jan. 23, 1944, by shell fragment. He was operated upon at 6:00 P.M., Jan. 23, 1944. The patient was in extreme shock when admitted to the field hospital. Examination revealed a penetrating wound of the right upper quadrant

of the abdomen and a severe compound comminuted fracture of the right tibia and fibula, middle third. Exploratory laparotomy was carried out through an upper midline incision (xiphoid to just above the umbilicus). Macerated hepatic flexure, ascending colon, and terminal ileum were found. Shell fragments lay free in the pelvis. No other intra-abdominal viscera were injured; extensive fecal soiling. The entire right colon and a portion of the right half of the transverse colon were removed, along with the first four inches of the terminal ileum. Long-sutured, spur, ileotransverse colostomy was constructed and brought out through the débrided wound of entrance. The fracture was débrided and a cast applied. In spite of supportive therapy of whole blood, plasma, glucose, and saline before and during operation in the postoperative course, the patient died Jan. 25, 1944. Autopsy revealed only the facts found at operation.

CASE 2.—A soldier was injured 9:00 A.M., March 12, 1944, by shell fragment. He was operated upon at 6:00 P.M., March 12, 1944. The patient responded to treatment for shock when admitted to the field hospital. Examination revealed a penetrating wound just below the costal margin in the right posterior axillary line and a left thoraco-abdominal wound with the wound of entrance in the tenth interspace, left midaxillary line. X-ray showed a small amount of clouding at the base of the left lung field, with no pneumothorax. A foreign body lay in the left upper quadrant of the abdomen just below the diaphragm. A foreign body from the wound of entrance on the right lay in the right lumbar muscles. Urine was grossly bloody on catheterization, at admission. Exploratory laparotomy was carried out through an upper midline incision, xiphoid to umbilicus. Right nephrectomy was done for a severely macerated kidney with large laceration through the pelvis of the kidney. Right colectomy was done for multiple perforations of the ascending colon and impairment of the blood supply to the cecum. A long, sutured, double-barreled, spur ileotransverse colostomy was constructed and brought out through a right McBurney incision. The foreign body was removed from the lumbar muscles. The foreign body in the left upper quadrant was removed from where it was found to be lying on the spleen without injuring that organ. Perforation of the left diaphragm was sutured from below. The penetrating wound on the left side of the chest was débrided. The left lung expanded under positive pressure and the wound was closed to prevent sucking. The patient died March 15. Autopsy revealed a purulent generalized peritonitis, paralytic ileus, and bilateral pneumonic consolidation of the lower lobes of both lungs.

CASE 3.—A soldier was injured 10:00 P.M., May 31, 1944, by shell fragment. He was operated upon at 3:30 A.M., June 1, 1944. Examination revealed a perforating wound of the abdomen, with its entrance in the upper midline just above the umbilicus, and exit in the right flank. He was in severe shock on admission to the field hospital but responded to shock therapy. Exploratory laparotomy was made through the upper midline incision. The right colon, hepatic flexure, and right half of the transverse colon were torn to shreds. There was a small perforation of the second portion of the duodenum and almost complete transection of the lower third of the stomach. Extensive muscle damage was present in both wounds. There was extensive peritoneal contamination from the colon and the stomach. The cecum, ascending colon, hepatic flexure, and right half of the transverse colon were removed. A long, sutured, double-barreled, spur ileotransverse colostomy was brought out through the left upper quadrant subcostal stab wound. Laceration of the stomach was sutured and perforation of the duodenum closed. The patient died forty-eight hours later. Autopsy revealed only the facts known at operation.

CASE 4.—A soldier injured 10:00 A.M., Feb. 19, 1944, was operated upon 8:00 P.M., Feb. 19, 1944. Examination revealed a penetrating wound of the abdomen, with the wound of entrance just below the right costal margin posterior to the axillary line. A missile (enemy rifle bullet, .30 caliber) could be felt beneath the skin in the back just to the right of the third lumbar vertebra. Exploratory laparotomy was made through the upper midline incision. The cecum and ascending colon, which were irreparably damaged; were removed. A long, sutured double-barreled, spur ileotransverse colostomy was brought out through a stab wound in the right upper quadrant of the abdomen. The foreign body was removed through a counter-incision posteriorly. The postoperative course was uncomplicated. The patient was evacuated to the base area on the fifteenth postoperative day; the spur was crushed in the fourth postoperative week. There was minimal erosion of the abdominal wall. The upper midline incision healed.

TABLE I. MORTALITY RATES

PROCEDURE	NO. OF CASES	NO. OF DEATHS	MORTALITY PER CENT
<i>Curative Resections</i>			
Right side			
Right hemicolectomy	49	14	28.6
Left side			
End-to-end anastomosis	21	4	19.0
Anterior resection or Hartman	14	0	
Modified Mikulicz	33	5	15.1
Total	117	23	19.6
<i>Palliative Operations</i>			
Right side malignancy	22	4	19.0
Left side malignancy	59	13	22.0
Total	81	17	20.9
<i>Simple Exploration</i>			
Right and left exploratory laparotomy	26	6	23.1
Total	224	46	20.5

resections were carried out with 12 deaths, a mortality of 29.2 per cent. Four Mikulicz type procedures after the fashion of Lahey⁴ were done with 2 deaths, a mortality of 50 per cent. A two-stage resection was done in 2 cases with no deaths. Two cases of hemicolectomy with ileostomy were recorded with no deaths (Table II).

TABLE II. RESECTIONS OF THE RIGHT COLON

OPERATIVE PROCEDURE	NO. OF CASES	NO. OF DEATHS	MORTALITY PER CENT
<i>Cancer</i>			
One stage	41	12	29.2
Mikulicz	4	2	50.0
Two stage	2	0	
<i>Polyposis</i>			
Colectomy with ileostomy	2	0	
Total	49	14	28.6

The causes of death are listed in Table III. Sepsis in the form of either localized or generalized peritonitis accounted for 57.13 per cent. of all the deaths. Pneumonia, cardiac failure, mesenteric thrombosis, and urinary tract infection account for the remaining 6 deaths.

TABLE III. CAUSES OF DEATH IN RIGHT HEMICOLECTOMY

CONDITION	NO.	MORTALITY PER CENT OF TOTAL
Generalized peritonitis	6	42.9
Localized peritonitis	2	14.3
Bronchopneumonia	2	14.3
Cardiac failure	2	14.3
Mesenteric thrombosis	1	7.0
Urinary tract infection with septicemia	1	7.0
Total	14	100.0

NEOPLASMS OF THE LEFT ABDOMINAL COLON

Of 142 lesions of the left side of the colon which were explored, 68 were resected, an operability rate of 47.8 per cent. There were 9 deaths in these 68 resections, a mortality of 13.2 per cent.

Three types of procedures were used in the operative attack on lesions of the left side, in part dependent upon location. There were 33 modified Mikulicz procedures after the method of Rankin,⁶ with 5 deaths, a mortality of 15.1 per cent; 21 resections with immediate anastomosis were done with 4 deaths, a mortality of 19 per cent, and 14 anterior resections or Hartman procedures (3) with no deaths (Table IV).

TABLE IV. RESECTIONS FOR LEFT SIDE OF COLON

OPERATIVE PROCEDURE	NO.	DEATHS	MORTALITY PER CENT
Modified Mikulicz	33	5	15.1
Resection and immediate end-to-end anastomosis	21	4	19.0
Hartman procedure	14	0	0.0
Total	68	9	13.2

The comparison of results of the modified Mikulicz procedure and the end-to-end anastomosis is of particular interest. Reports in the literature show a division of opinion among surgeons with respect to the type of procedure which should be used. Some favor resection with immediate anastomosis while others advocate the Mikulicz operation or one of its modifications. Among the advocates of the modified Mikulicz procedure are Rankin,⁶ Cattell,² Jones,³ and Mayo and Twyman.⁵ Some of the proponents of resection and aseptic anastomosis are Stone and McLanahan,⁸ Whipple,¹⁰ Wangensteen,⁹ Zinninger and Hoxworth,¹¹ and Allen.¹ If mortality and morbidity do not differ in the two procedures, resection of the bowel with immediate restitution of its continuity would seem the more desirable.

MODIFIED MIKULICZ RESECTION

There were 33 modified Mikulicz resections of the left side of the colon with 5 deaths, a mortality of 15.1 per cent (Table I). Of these resections, 32 were for carcinoma and 1 for sigmoiditis. The causes of death are listed in Table V.

Sepsis was responsible for all of the deaths in this group. Peritonitis was responsible for 60 per cent. A brief analysis of the deaths follows.

1. T. H. (No. 40-12891) had marked obstruction of the colon at the time of operation and a note was made that it required the largest type of crushing clamp to grasp this dilated limb. The patient died with gangrene of loops of colostomy and generalized peritonitis.

2. M. P. (No. 42-4900) had marked obstruction and dilatation of the bowel at operation and subsequently the colostomy pulled out of the proximal clamp and retracted into the free abdominal cavity. The patient died of generalized peritonitis.

3. B. S. (No. 44-10666) had had a cecostomy done nine weeks prior to admission to the University Hospital. This functioned poorly and at operation the bowel was dilated twice its normal size. The patient died of generalized peritonitis.

4. A. J. (No. 44-12112) had far-advanced tuberculosis and was mentally incompetent. She had an obstruction on admission and had a transverse colostomy nineteen days preceding resection of the sigmoid and urinary bladder. The appendix was removed at the same time because it showed evidence of obstructive changes. This patient died of uremia, wound infection, and cachexia.

5. J. H. (No. 42-10413) developed a urinary tract infection, perinephric abscesses, and became uremic postoperatively. The cause of death was urinary tract infection and uremia.

This review of the deaths graphically illustrates the adage that obstructed bowel should always be properly decompressed before resection is carried out. Rankin⁷ recently re-emphasized that obstructed and ulcerated bowel allows virulent organisms to penetrate the bowel, and that even the mere manipulation is sufficient to cause peritonitis.

The closure of the colostomy presented a major problem in this group of resections. Twenty-two patients had 1 closure of the colostomy and one had 3 closures of the colostomy, a total of 25 closures with 12 disruptions, a rate of failure of 48 per cent. There were 11 fecal fistulas in the 23 patients at the time of discharge. When last heard from 6 of these had healed, this leaving only 5 persistent, and one of these may be ruled out because of death from

TABLE V. CAUSES OF DEATH IN MODIFIED MIKULICZ RESECTION

CAUSES	NO.	PER CENT OF TOTAL MORTALITY
Generalized peritonitis	3	60
Wound infection and cachexia	1	20
Bilateral perinephric abscesses	1	20
Total	5	100

recurrence of the carcinoma. Therefore, there have been 4 persistent fistulas in 23 patients, or 17 per cent. There were 5 patients in whom no attempt was made to establish bowel continuity; 2 of these died of carcinoma in the interim, 1 had a recurrence, and 2 have never returned.

RESECTION WITH IMMEDIATE END-TO-END ANASTOMOSIS

There were 21 resections with immediate end-to-end anastomosis of the colon with 4 deaths, a mortality of 19 per cent. Of these resections, 17 were for carcinoma of the colon, 1 for metastatic malignant melanoma, and 3 for carcinoma of the stomach with associated extension to the colon (Table VI).

A brief analysis of the deaths follows (Table VII).

TABLE VI. RESECTION WITH IMMEDIATE END-TO-END ANASTOMOSIS

CONDITION	NO.	DEATHS	PER CENT
Primary malignancy of colon	17	3	17.6
Malignancy with extension to colon	4	1	25.0
Total	21	4	19.0

TABLE VII. DEATHS IN GROUP OF END-TO-END ANASTOMOSES

Generalized peritonitis	3
Cardiac failure	1
Total	4

1. J. K. (No. 39-15433) died on the eighth postoperative day of generalized peritonitis, the signs and symptoms of which became present on the seventh postoperative day. Autopsy revealed dehiscence of the anastomosis with leakage.

2. A. P. (No. 42-1038) was admitted with a rather advanced obstruction. A preliminary decompressing cecostomy was performed and fourteen days later resection and end-to-end anastomosis were carried out. The patient developed an intraperitoneal abscess which was drained on the twelfth postoperative day. Her course was steadily downhill and she died on the thirty-first postoperative day. Autopsy showed dehiscence of the anterior wall of the colocolostomy.

3. T. F. (No. 43-7387) had resection of a malignancy of the splenic flexure. The tumor was difficult to remove and the colon was broken into three times at operation. A wound infection and bronchopneumonia developed postoperatively on the ninth and eleventh postoperative days, respectively. On the twenty-eighth postoperative day an intraperitoneal abscess was drained. The patient died the same day and autopsy revealed a generalized peritonitis with dehiscence of the suture line in two places.

4. E. G. (No. 43-8709), who had diabetes with auricular fibrillation, had a subtotal gastrectomy and colectomy for carcinoma of the stomach with extension to the colon. She developed symptoms of a left femoral embolus on the first postoperative day and this was removed. Death occurred on the second postoperative day from auricular fibrillation and cardiac failure. No autopsy was obtained.

In this group of patients there were 9 decompressing procedures, either transverse colostomy or cecostomy; 7 of these were done prior to the date of resection, and 2 were done at the time of the resection. In this group there was only one death, a mortality of 11.1 per cent.

The decompressions were closed in 5 cases and there were two breakdowns, a failure rate of 40 per cent. One sigmoid colostomy previously performed at

another hospital was removed at the time of resection with a good end result. Three cecostomies closed spontaneously.

Comparison of the modified Mikulicz procedure and the resection with immediate end-to-end anastomosis follows: There was little choice as far as sex was concerned, with 17 women and 16 men in the modified Mikulicz series, and 11 women and 10 men in the end-to-end series. The average age was 59.4 in the Mikulicz series and 61.7 in the end-to-end series. The average number of hospital days was 56 in the Mikulicz group and 43 in the end-to-end group. This includes all days spent in the hospital, both pre- and post-operatively. Of the 28 patients who survived in the Mikulicz group, there were, at the time of the last follow-up, 5 persistent fecal fistulas. If the patient with recurrence is ruled out of this group, there remain 4 with unhealed fistulas or 17.0 per cent of the operative survivals. In the 17 patients who survived the operative procedure with end-to-end anastomosis, there were 2 persistent fistulas present, or 11.7 per cent. There were 13 wound infections in the Mikulicz group, or 39.3 per cent, and 6 wound infections in the end-to-end group, or 28.5 per cent. The mortality has been compared in Table IV. There was an over-all mortality rate of 15.1 per cent with the Mikulicz procedure and 19.0 per cent with the end-to-end anastomosis. In order to gain a better comparison of the trend which the two procedures are taking, the cases are broken down into separate years in Table VIII.

TABLE VIII. COMPARISON OF MODIFIED MIKULICZ PROCEDURES WITH RESECTION AND IMMEDIATE END-TO-END ANASTOMOSIS BY YEARS

YEAR	MIKULICZ			END-TO-END		
	NO.	DEATHS	MORTALITY PER CENT	NO.	DEATHS	MORTALITY PER CENT
1937	1	0		0		
1938	2	0		0		
1939	1	0		4	1	25.0
1940	6	1	16.6	0		
1941	6	0		0		
1942	6	2	33.3	3	1	33.3
1943	4	0		5	2	40.0
1944	7	2	28.6	9	0	
Total	33	5	15.1	21	4	19.0

ANTERIOR RESECTION

An anterior type of resection or Hartman procedure was carried out in 14 cases, with no deaths. This is remarkable when it is remembered that the procedure was used in poor-risk subjects and on low-lying lesions. It is, however, not attended with any of the dangers inherent in the operations which re-establish the continuity of the bowel. There were 10 men and 4 women in this group with an average age of 61.1. Wound infection and disruption occurred in only two instances (Table I).

PALLIATIVE PROCEDURES

There were 19 sidetracking operations for lesions of the right side with 4 deaths, a mortality of 21 per cent. There were 10 sidetracking operations for lesions of the left colon with 5 deaths, a mortality of 50 per cent (Table IX). That palliative operative therapy of carcinoma of the colon does carry a high mortality rate is well recognized. Jones³ points out that the type of patient who receives this therapy is probably lacking in the essentials of adequate vitamins and proteins due to the general debility which is caused by the disease.

TABLE IX. PALLIATIVE OPERATIONS

PROCEDURE	RIGHT SIDE			LEFT SIDE		
	NO.	DEATHS	MORTALITY PER. CENT	NO.	DEATHS	MORTALITY PER. CENT
Side tracking	19	4	21.0	10	5	50.0
Cecostomies	3	1	33.3	10	4	40.0
Colostomies	0			39	4	10.2
Total	22	5	22.7	59	13	22.0

We continue to accept the high mortality in this group for the comfort which it affords in the successful cases.

Of the 9 deaths which occurred from sidetracking procedures, 6 were due to generalized peritonitis, 1 was due to shock, 1 to pneumonia, and 1 to mesenteric thrombosis. Of the 5 deaths occurring after cecostomy, 4 were due to peritonitis. In 2 of these cases perforation of the tumor with generalized peritonitis was present at the time of cecostomy and in a third, the tumor perforated at a later date. In one case the cecostomy retracted and a fatal peritonitis resulted; in the fifth case with cecostomy, evisceration occurred and death ensued from shock.

Of the 4 deaths which occurred following colostomy, 2 were due to cardiac failure and the cause of the other 2 was undetermined.

Over and above all of the foregoing groups in which operative procedures were carried out upon the colon, there were 26 patients who had simple exploratory laparotomy with or without biopsy of metastatic areas. Of this group 6 died, a mortality of 23.1 per cent (Table I).

SUMMARY

The operative results of colon surgery for neoplastic disease covering the period between Jan. 1, 1937, and Dec. 31, 1944, have been reviewed. Two hundred twenty-four patients with colon malignancy were treated and the results have been tabulated.

CONCLUSION

1. There is no one operative procedure which can be applied to all neoplasms of the colon.

2. There are an increasing number of resections with immediate end-to-end anastomosis being performed in this clinic.

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OBSERVATIONS ON LARGE BOWEL PERFORATIONS

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IN THE past, analyses of the question of large intestine perforations have revolved principally about the subject of diverticulitis and of its complications. Clinical experience has demonstrated that in any patient over 40 years of age, who gives an antecedent history of lower abdominal discomfort and presents a febrile course and a picture of local or of generalized peritonitis, the problem frequently resolves into the treatment of a complication of diverticulitis. Nevertheless, when one reviews the pathologic material, it is noted that large bowel perforations, as diagnosed clinically, must be interpreted in terms of additional etiologic factors besides diverticulitis and its complications. In the last ten years in this hospital, among a total of 1,400 necropsies there have been recorded nineteen cases (1.35 per cent) of large bowel perforations, each with the complication of extraluminal abscess formation, localized peritonitis, or generalized peritonitis. Ten, or slightly over one-half of these, were attributable to a perforation complicating diverticulitis. In six cases a large bowel malignancy was present. A single instance is recorded of ovarian carcinoma metastasizing to bowel wall and producing communicating ileal and sigmoidal perforations. In the two remaining autopsies, mechanical perforations from within were found and these will be discussed in detail further on. We have had no autopsies in cases of perforation secondary to cecal tuberculosis or to ulcerative colitis. Examples of the former are encountered with greater frequency in older treatises on this subject. Regarding chronic ulcerative colitis, Rankin, Barger, and Bouie reported the incidence of perforation to be 3.4 per cent in their large series of patients with this disease.

The cases in which autopsies were done, cited here in detail, are exemplary of the subject presented. All are recordings of personal experiences in the past year.

DIVERTICULITIS AND PERFORATION

CASE 1 (No. 102537).—A 59-year-old white man, an investigator, was admitted to the hospital Nov. 27, 1944. Four weeks prior to admission he had experienced a chill, followed by persistent diarrhea. Ten days after this episode there commenced lower abdominal pain, chiefly on the left side. The diarrheal stools became reduced and never exceeded two or three tablespoonfuls. Later he noted abdominal distention. Anorexia and weakness were marked and a weight loss of fifty pounds was attributed to the present illness. The patient had been bedridden for seven days. Prior to admission, a barium clysma performed by his local physician had demonstrated an obstructive lesion of the sigmoid and diverticulosis. The family history was noncontributory. The past history was not significant except for ankle swelling of one month's duration. Physical examination revealed an acutely ill patient complaining of severe abdominal pain. The blood pressure was 90/70, the temperature was 102.4° F., and the pulse 120. An edema of the extremities and trunk was noted. The abdomen was domelike and distended. Marked tenderness and rigidity were present over the left lower quadrant. The colon-down to the sigmoid was distended and visible through the abdominal wall. The laboratory data included: hemoglobin 80 per cent, red blood cells 3.9 million, white blood cells 8,900 with 78 per cent polymorphonuclear leucocytes including 26 per cent immatures; the urine showed 3 plus albumin and numerous casts; urea nitrogen

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Fig. 1.—Roentgenogram of lesion in patient in Case 1. Obstruction and probable extraluminal extravasation of barium are exhibited.



Fig. 2.—Prepared and mounted pathologic specimen from Case 1, showing columns of diverticula. The obstructive stenosis of the lumen is demonstrated at the lower area. Multiple perforated abscesses were demonstrable.

was normal. The clinical diagnosis was intestinal obstruction due either to a sigmoidal neoplasm or to diverticulitis. The day following admission a cecostomy was performed under local anesthesia to relieve the obstruction. Despite adequate drainage through the cecostomy, the patient's course was unfavorable, and he died on the second postoperative day.

The autopsy performed on the day of death demonstrated an acute generalized fibrino-purulent peritonitis; all intraperitoneal recesses contained pus, and small and large bowel loops were coated with heavy layers of fibrin. The large bowel proximal to the sigmoid was enormously distended, and the wall thinned and friable. The lower descending colon and the sigmoid were fixed in a thickened plastic mass along the promontory of the sacrum. The mesenteric fat surrounding the bowel was firm and indurated, and many pus accumulations were encountered. Mucosal diverticula were present throughout the entire large bowel as far proximally as the cecum; these were as large as 1 cm. in diameter and usually contained an inspissated fecal plug. Several of the diverticula in the descending colon and sigmoid were covered with thick, indurated tissue with here and there a fresh fibrin surface covering. Occasional areas of frank suppuration were present within these diverticula. At a point 25 cm. from the anal margin, the thickening and induration about the bowel wall were maximum and a distinct stricture was evident on intraluminal exploration and probing; this was produced by the stenosing perisigmoidal, adhesive mass.

Comment.—This case is reviewed in detail because it illustrated significant features and sequences of diverticulitis with its complications and sequelae. First, there was an extensive anatomic alteration in that the diverticula were not limited to the sigmoid as is usually the case, but extended completely around the large colon to the cecum. Second, there were exhibited several of the possible clinical and pathologic complications of diverticulitis: (a) gross and microscopic evidences of a peridiverticular chronic inflammatory reaction; (b) abscess formation; (c) perforation of inflamed diverticula accounting for generalized peritonitis; (d) progressive intestinal obstruction with stenosis as the result of chronic, repeated, perisigmoidal inflammatory insults. Another possible complication, namely, fistula formation, may well have resulted had not the obstruction and perforation terminated the life of this patient. It is not uncommon that a sealed-off peridiverticular abscess ruptures into an adjacent viscus or externally on the skin. That diverticulitis is the most common offender for sigmoidovesical fistulas is well recognized. The most uncommon complication of diverticulitis is metastatic suppuration.

This case is illustrative of the seriousness of the disease and of its complications. The literature is abundant with statistics on diverticulitis and its sequelae but these vary widely depending upon how each series is recorded. For ample reviews the reader is referred to the publications of Ochsner, of Arnheim, and of Young and Young. Compilation statistics would seem to have indicated that diverticula exist in approximately 3 to 5 per cent of all colons, but it must be remembered that this figure would be a good deal higher in patients over 40 years of age. For all clinical purposes diverticulitis and its complications are practically unknown before the fifth decade. In the compilation statistics of Young and Young, diverticulitis developed in 34 per cent of colons with diverticula. Arnheim's review noting 834 compiled cases of diverticulitis quoted the incidence of abscess formation to be 4 to 39 per cent in respective individual reports, with a total average of 19 per cent; and on a similar basis the incidence of peritonitis varied from 0.8 to 25 per cent with a total average of 12 per cent. Despite these wide variations in reports, the over-all significance and relative frequency of perforative complications are established. One feature of the disease which is distinctly illustrated by statistics is the fact that there is absolutely no etiologic relationship between the incidence of sigmoidal carcinoma and diverticulitis.

This case demonstrates the difficulty encountered in the differential diagnosis of obstructing lesions of the sigmoid colon. It was originally felt from the barium clysma study that probably a neoplasm was being dealt with. As high as a 15 per cent radiologic error is quoted in differentiating sigmoidal obstructive peridiverticulitis and malignancies. One must be aware that malignancies and stenosing sigmoiditis secondary to diverticulitis occur in the same age group and that therefore each case must be individualized. A carefully taken history possibly revealing cyclic febrile episodes with lower abdominal symptoms in the past would favor the diagnosis of purely inflammatory pathology.

CARCINOMA AND PERFORATION

CASE 2 (No. 101922).—A 59-year-old white man, a newshawk, was admitted to the hospital with the complaint of right lower abdominal pain of four weeks' duration. The pain was intermittent in nature, probably noncolicky, and occasionally radiated into the scrotum. There was no vomiting and daily bowel movements were normal. The patient had always felt well except for an undefined back condition for which x-ray treatments had been given one year before admission. He had allegedly contracted a chancre at the age of 29 but had never received treatment. The family history was not significant. On physical examination the patient was obese and appeared moderately ill. The temperature was 100.2° F., the pulse 80, and the blood pressure 120/72. Pertinent findings were confined to the abdomen where an orange-sized, firm, tender mass was felt in the right lower quadrant. Laboratory data included: hemoglobin 69 per cent, red blood cells 3.4 million, white blood cells 12,000 with 72 per cent mature polymorphonuclear leucocytes; urea nitrogen was 14.0; the Wassermann was negative; the urine showed a trace of albumin and occasional red and white cells; the stool guaiac was negative for blood; the sedimentation rate was 42.0 mm. in one hour. The barium clysma studies demonstrated an obstructing lesion of the cecum, interpreted as follows: "The lesion probably represents a carcinoma of the cecum but the possibility of an intussusception or an appendiceal abscess must also be considered."

The patient was prepared for operation with the usual measures, including transfusions and sulfasuxidine. At the laparotomy performed on the tenth day following admission, there was a large, fixed, ileocecal mass extending posteriorly and toward the pelvis. This was regarded as an inoperable malignancy and a palliative ileotransverse colostomy was performed. On the third postoperative day a wound dehiscence was noted; through-and-through closure of this was done immediately under general anesthesia. The ensuing course was unfavorable, and he died on the third postoperative day following wound closure (sixth day following laparotomy).

At autopsy performed the following day, there were no evidences of local or generalized peritonitis; all peritoneal surfaces were smooth and glistening, and no intraperitoneal abscess pockets were encountered. The wound and anastomotic sites were well sealed off. A bulging retrocecal mass was present, and when the peritoneum of the right lateral gutter was stripped off, a tense, extraperitoneal abscess overlying the inner aspect of the iliacus muscle was entered. An estimated 500 c.c. of turbid pus was evacuated from the abscess cavity. The abscess was in direct communication through a pin-point sized opening with the center of a large, fungating, polypoid carcinoma of the cecum. Elsewhere, along the course of the large bowel and rectum there were observed several mucosal polyps, the largest measuring 1 cm. in diameter. Microscopic examination demonstrated the cecal malignancy to be a mucoid adenocarcinoma, probably Grade III. In addition, the largest of the several adenomatous polyps proved to be an early Grade I adenocarcinoma. There were no microscopic evidences of lymph node metastases in the drainage fields of either of the two malignancies.

Comment.—This case illustrates a large bowel neoplasm with perforation and secondary suppuration. It is not the uncommon experience of the surgeon dealing with large numbers of colon malignancies to have the disease come to his attention for the initial time because of symptoms referable to perforation of the tumor with attendant abscess formation or peritonitis. It has been estimated that as many as 25 per cent of all colon malignancies come to medical consultation for the first time because of perforation. Rankin, Barger, and Bouie noted that the splenic flexure had been the most frequent site of perfora-

tion. In our autopsies of the last ten years there are recorded thirty-seven cases of large bowel malignancy. In six of these there was a perforation of the carcinoma. Thus, in our experience, 16 per cent of colon malignancies have perforated before treatment. This figure is based on comparatively few cases and is probably high, for the patient with a perforation bears a grave prognosis and is more likely to succumb in the hospital. Four of the perforations of the large bowel associated with carcinoma were in the sigmoid and two were in the cecum. In a series from the Mayo Clinic of 1,502 consecutive cases of colon malignancy, at operation 144 (9.4 per cent) were regarded as complicated by perforation. Instances are recorded of fecal fistula associated with a perforated carcinoma of the large bowel. This probably would have been the situation in the case just cited had the abscess dissected extraperitoneally and decompressed on the anterior abdominal wall.

The prognosis in perforated large bowel carcinoma is extremely discouraging. Even the initial operative procedure of a proximal, decompressing colostomy or cecostomy usually with drainage to the point of perforation or abscess formation bears a high mortality; also, when the tumor has reached the anatomic stage of perforation, it is usually inoperable because of fixation and/or metastatic spread.

INTRALUMINAL MECHANICAL PERFORATION

CASE 3 (No. 96102).—A 71-year-old white housewife was in this hospital one year prior to the present illness. At that time the diagnosis was hypertensive cardiovascular disease and diabetes, and she was discharged on a maintenance dose of digitalis and a controlled diabetic diet with 25 units of protamine zinc insulin. Six days prior to this admission she experienced sudden lower abdominal pain and had five to six bowel movements a day. She took no food and is said to have stopped regulating the diabetes. During the two days preceding admission she vomited five times and noticed bright red blood in the stools. Crampy pain, localized to the lower quadrants, had continued. On physical examination the temperature was 100° F., the pulse 108, respiration 30 and labored; the blood pressure was 130/75. She appeared acutely ill and dehydrated. There were no signs of cardiac decompensation. The lower abdomen was distended with dilated and hyperresonant bowel. There was no shifting dullness, no obliteration of liver dullness. The left lower quadrant was acutely tender and spastic. No masses were palpable. Rectovaginal examination yielded no distinct findings. The admission laboratory data included: white blood count 7,680 with 82 per cent polymorphonuclear leucocytes of which 55 per cent were immatures; the urine showed a trace of albumin, 1 per cent sugar, strongly positive acetone, and occasional white blood cells and red blood cells. It was felt that the patient had a peritonitis possibly due to perforation of an obstructing large bowel malignancy. The diabetes was controlled by hourly urine studies and parenteral fluids and insulin; an exploratory operation was performed fifteen hours after admission. Thick pus was encountered in the abdominal cavity; this grew *Bacterium coli* subsequently. The left Fallopian tube was dilated and convoluted, but there was no torsion. The adjacent large bowel seemed indurated. Otherwise there was no evident pathology. Penrose drains were inserted, and the operation terminated. Post-operative measures were supportive and included parenteral digitalization and fractional urine diabetic control. However, dyspnea and toxemia supervened, a shocklike picture arose, and the patient succumbed fifty-two hours after operation.

At autopsy it was seen that the peritonitis had apparently resolved since operation, for the small bowel and visceral surfaces were smooth and glistening; there was no free fluid. Partially enveloping the sigmoid in the left gutter was a well-circumscribed abscess. Adjacent to this an edematous and hemorrhagic left tube was adherent to the lower sigmoid. When the uterus was elevated forward, firm adhesions were identified extending from the posterior leaf of the left broad ligament to the sigmoid. Upon opening the sigmoid along the anterior longitudinal band there was encountered, at the level of the pelvic brim and 25 cm. above the anal margin, a bone resembling a fowl bone measuring 5½ cm. in length. This bone was impacted obliquely across the lumen with its bifurcated left edge imbedded through the sigmoid wall adjacent to the area where the Fallopian tube was adherent to the colon;

the other bone edge had penetrated the opposite side of the bowel into a well-scaled-off perisigmoidal pocket. The mucosa surrounding each area of penetration was necrotic. The left gutter abscess extended upward from the penetration of the bifurcated edges of bone on the left side. In addition to the gastrointestinal tract pathology, other findings included marked congestion of the lungs and bilateral hydrothorax, advanced arteriosclerotic heart disease, and cardiac cirrhosis of the liver.



Fig. 3.—Specimen from Case 3 showing perforating bone in situ, in sigmoid. A penetration was observed at each end of bone.



Fig. 4.—Transversely impacted bone extracted from sigmoid of patient in Case 3.

Comment.—This case adds another interesting one to the long list of reports on complications produced by ingested foreign bodies. The patient gave no history of having swallowed the bone, which appeared as to be some sort of fowl bone. It is remarkable that the foreign body, in this instance much elongated and with sharp, bifurcated edges, traversed the natural fixation points and narrowed ostia of duodenum and ileocecal regions, to finally impact transversely in the redundant sigmoidal fold. In most of the case reports of foreign bodies perforating the colon, the offending agent was usually of smaller dimensions. Had not severe myocardial insufficiency supervened, it is not unlikely that this patient might have survived the perforation, for, at necropsy the peritonitis was resolved into well-localized abscess formation. It has been the

experience of authors who have reported colon perforations due to foreign bodies that the prognosis in such perforations has been excellent, in contrast to those of the stomach and upper intestinal tract.

Henderson and Gaston, in 1938, reported on fifty-seven collected cases of foreign body perforations of the gastrointestinal tract and added nine of their own cases. They reviewed in detail the entire subject of the fate of ingested foreign bodies. They concluded their analysis with the recommendation that operative investigation is indicated when a twenty-four hour period of observation has revealed no progress in the passage of the foreign body with relation to adjacent viscera. In their collected series of perforations, a large number occurred in the stomach. Macmanus, in 1941, reviewed cases of gastrointestinal perforations caused by foreign bodies. He assembled ninety-three cases from the literature and contributed two of his own, one of which was a perforation by a piece of wire, of a loop of bowel incarcerated in a hernial sac. Seventy-three per cent of the perforations were in the lower ileal and cecal region, and a Meckel's diverticulum was a frequent site of penetration. Fifteen instances of colon perforation are recorded, and in these the prognosis was generally excellent. The list of offending agents in gastrointestinal perforations by ingested foreign bodies is an imposing and familiar one, with toothpicks and fishbones probably being the most frequent. In children the swallowed opened safety pin provides a not unusual problem.

The treatment of large bowel perforations by foreign bodies is similar to that of perforations secondary to primary colon disease. Early and adequate intraperitoneal drainage, proximal decompression (colostomy), and meticulous attention to the postoperative adjuncts of decompression (Miller-Abbott tube) and of blood chemistry and fluid balance control are the weapons at command. Rarely is it possible to exteriorize the perforated segment of bowel.

CASE 4 (No. 39213).—This was the fifth admission of a 26-year-old white man, an artist, who came to the hospital acutely ill. He offered the history of having had "loose bowels" for several days, which he had attempted to control twenty-four hours before admission with a high enema. The latter procedure was followed within one-half hour by the onset of sudden and diffuse abdominal pain. The pain persisted and was poorly localized but soon became so severe that he sought hospitalization.

This patient was first seen in the hospital in October, 1933, for complaints referable to an anal fistula, presumed to have been syphilitic in origin because of a 4 plus blood Wassermann. This lesion failed to respond to antisyphilitic treatment. On a second admission, in May, 1934, a proctoscopic examination revealed a broad anorectal scar; the biopsy report was chronic ulcerative proctitis with polypoid hypertrophy of mucous membrane; there were no evidences of tuberculosis and no vascular changes suggestive of syphilis. A sigmoidostomy was performed to by-pass the fecal stream and to allow for adequate local rest and irrigation therapy of the rectal pathology. On a third admission, in March, 1937, the sigmoidostomy was closed operatively. On a fourth admission, in December, 1944, there were complaints and findings suggestive of glomerulonephritis. Physical examination on the final admission revealed a severely ill patient. The temperature was 100.6° F.; the pulse was 140; the blood pressure was 116/78. The abdomen was boardlike and exquisitely tender throughout. Within a few hours of admission, a laparotomy was performed. Cloudy, yellow fluid with suspended particles filled the abdominal cavity; fecal material was exuding from a perforation in a small gangrenous patch of the lower anterior sigmoid. A decompressive transverse colostomy was performed, and drains were inserted to the site of perforation. Postoperatively, the patient exhibited severe renal decompensation, and he expired in uremia on the sixth postoperative day.

At autopsy, the margins of the recent transverse colostomy were well sealed off. The lower abdomen and pelvis contained a large amount of hemorrhagic, purulent fluid and here the bowel loops were coated with fibrin. At the rectosigmoid junction 18 cm. from the anus there was a gangrenous zone along a 2½ cm. length of anterior bowel wall; several elongated, through-and-through disruptions in the wall were seen here. Above (proximal to) this re-

gion, the sigmoid was bound by dense adhesions to the anterior abdominal wall underlying the scar of the old sigmoidostomy. When these adhesions were separated, it was seen that the lower sigmoid was rotated and angulated in the anteroposterior plane in such fashion that it formed a complete S malformation upon itself within a very limited space; the two limbs of the S were tightly compressed and the total length of reduplicated sigmoid here was only about $3\frac{1}{2}$ cm. This anatomic alteration had produced a ball valve type of retrograde obstruction of the lower sigmoid with the rectosigmoid below corresponding to a large redundant sac. It was at the anterosuperior portion of this sac that the gangrenous patch was present. There were no microscopic manifestations of specific lesions (tuberculosis or syphilis) in the rectal or sigmoidal walls or in the supporting connective tissues. Finally, there were microscopic evidences of a fulminating, malignant nephrosclerosis.

Comment.—This case may be classified with the previously cited one, inasmuch as it represents rupture of the rectosigmoid as a complication of intraluminal mechanical insult. Rupture by direct contact of an extremely long enema tip cannot be entirely eliminated as a consideration here, although the distance of the perforation from the anal margin would speak against this possibility. However, from the autopsy findings, it may be presumed that the combination of an old postoperative retrograde obstruction of the sigmoid and the sequence of a generously administered enema followed by onset of severe abdominal pain furnish evidences of fluid pressure rupture of the rectosigmoid. Cases of rupture of the bowel by an enema are recorded. It would seem that previously existing retrograde, segmental obstruction as was present here would be necessary to make possible rupture by a vigorous enema, for the gradual distensibility of the entire colon is enormous. In the case under consideration, the enema must have flowed in under very great pressure.

In 1931, Burt recorded from the literature and from his own cases a total of forty-four pneumatic ruptures of the bowel; the sigmoid was the most frequent site of rupture. He gathered some interesting experimental evidence on the air pressure necessary to rupture various segments of human bowel removed at autopsy. The average pressure required to rupture sigmoid bowel was 4.99 pounds per square inch. In the adult the ileum was the most resistant segment, an average of 8.36 pounds per square inch having been necessary to disrupt all layers. Higher pressures were generally necessary to produce rupture in the bowel of children. Burt's experiments were carried out at a fixed rate of air filling of the closed segment of bowel, namely, .38 pounds per second. It would seem that the rate of increasing intraluminal pressure would be an additional variant in determining the pressure at which the bowel ruptures.

SUMMARY

1. Experiences with large bowel perforations are analyzed.
2. Nineteen autopsies were recorded over a ten-year period. Perforation associated with diverticulitis accounted for ten of these deaths, seven were due to malignancy, and the remaining two to perforation by mechanical agents within the lumen.
3. Four recent autopsies in which large bowel perforations were revealed are cited critically and in detail, and a clinicopathologic survey is made in each instance.
4. The morbidity and mortality in diverticulitis complicated by perforation are distressingly high.
5. Probably between 10 and 20 per cent of primary large bowel malignancies first come to medical attention with the complication of perforation. The prognosis is extremely grave in this group.

6. Two unusual cases of perforation of the sigmoid due to intraluminal insult are recorded: one was due to perforation of an impacted fowl bone in a patient who gave no history of ingestion of the foreign body. The second case was one of rupture of a rectosigmoid following a vigorously administered enema; the lower sigmoid was anatomically sharply angulated as a result of an old operative procedure.

7. Treatment of perforation of the large bowel from any cause is essentially the same: early and generous drainage with a minimum of manipulation of the site of penetration and a proximal decompressive colostomy are the indicated surgical measures.

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SMALL BOWEL STRICTURE FOLLOWING IRRADIATION THERAPY FOR CARCINOMA OF THE FUNDUS UTERI

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DAMAGE to the intestine following irradiation therapy for cervix cancer is well known. The attention of the profession was first called to this complication in the early 1930's by Jones¹ in this country and Pemberton,³ Jeanneney and Berard,⁴ and others abroad. Since then, several careful analyses of series of cases have been reported. In most instances the terminal sigmoid and rectum are affected. There is a proctosigmoiditis, with symptoms of diarrhea, tenesmus, blood, mucus, etc. Later obstructive strictures may ensue. Although less common, all series contain a few cases in which the terminal ileum was damaged, causing more violent symptoms of small bowel obstruction, nausea, abdominal pain attacks with distention, etc.

In most of these cases, the damage has followed heavy radium dosage. Therapeutically, the effects of radium are produced within the confines of an area 5 to 6 cm. in all directions from the cervix. A heavy loop of sigmoid may fall into the pelvis, a loop of ileum similarly may happen to be in the pelvis, or had been bound down in the pelvis because of adhesions from a previous pelvic operation or old pelvic inflammation.

Another type of damage is widespread ileal damage (in contrast to localized lesions) thought by McIntosh² "undoubtedly a product of heavy x-ray dosage, almost invariably through large portals 12 by 16 cm." Here there is widespread fibrosis with multiple adhesions of the small bowel widespread in the abdominal cavity. Martin⁵ has shown that in dogs "irradiation of the whole abdomen produced various grades of toxemia, many of which were fatal . . . true roentgen sickness in many instances resulted from the effect of roentgen rays upon intestinal mucosa." Martin further remarked that "intestinal damage is still produced when vigorous attempts are made to cure advanced cases of cancer of the uterus with roentgen rays." Symptoms may start from two months to five years or longer after treatment has been given. Although, as stated, most instances of this peculiar damage have followed heavy irradiation, in an occasional instance it has followed years after very light irradiation. One of Schreiner's⁶ patients developed obstruction necessitating small bowel resection two years after treatment. "The dosage was not excessive, a small dose of roentgen rays, and two 400 mg. hour intrauterine radium applications."

Recommendations to avoid these unfortunate sequelae have been various. They include (1) weaker radium dosage, spread over longer time periods; (2) avoidance of heavy treatment dosages in attempts to cure far-advanced cases; (3) measures aiming to get the coils of ileum or sigmoid out of the pelvis during treatment: full urinary bladder, high Trendelenburg position (difficult to carry out routinely with twenty to thirty daily treatments or the present-day million volt machine); (4) careful preliminary investigation of patients who have had previous pelvic operations and avoidance of therapy if the bowel is suspected of being fixed to the posterior surface of the uterus, perhaps laparotomy and inspection before treatment is instituted. Meigs⁷ thought-

fully remarked that one-half of their cases had been in the early operable group; perhaps operation would have been safer than irradiation.

As to treatment of these bowel sequelae of irradiation, the tenesmus, diarrhea, etc., which are frequent concomitants of the usual course of therapy to cervix cancer, usually subside in several weeks. Some patients with narrowing have been treated with bland diet and bland rectal irrigations, and have become comfortable after several months even though narrowing still persisted. An increasing number have come to operations, such as permanent colostomy, liberation of adhesions, resection of sigmoid or ileum.

Strictures have been reported two months to five years after treatment. In such cases it may be very difficult to tell whether the cramps, abdominal distention, nausea, etc., are due to abdominal extension of the carcinoma or slowly forming strictures. The only differentiation is careful observation; if the patient's general health remains good and does not go downhill as a cachetic terminal malignancy should, operative exploration is warranted. It has been observed that the barium meal does not always show the "multiplicity or extent of these small bowel lesions" (Pightal⁸). Jones also commented on these difficulties in clinical diagnosis in 1935.

In practically all of the reported cases the pathologic condition has followed treatment for cervix cancer. In conversation with several radiologists, it was doubted that irradiation treatment for cancer of the fundus would produce radiation stricture. Nevertheless, three case reports of bowel damage following treatment for corpus carcinoma were found. A fourth is herewith added in which bowel damage followed radium treatment for benign hyperplasia.

Aldridge⁹ reported that one intestinal injury (proctosigmoiditis) followed treatment of forty-seven patients with carcinoma of the fundus uteri. The cell type was grade 3.

Schreiner,⁶ reporting five cases of bowel damage, stated that the second case was that of a uterine carcinoma, and the patient developed obstruction in the sigmoid which required colostomy eight years after treatment.

Cascaden, Kasabach, and Lenz,¹⁰ detailing fifteen case reports, described Case 9 as follows: Adenocarcinoma of the corpus stage 1 League of Nations. Treatment factors were: Radium into uterus 100 mg. 30 hr. = 3,000 mg. hr., 35 days later 112 mg. in uterus 24 hr. = 2,700 mg. hr., 19 days later roentgen treatment—2 anterior fields 10 by 10 cm., 52 Rx in 63 days; 19 days later roentgen treatment—2 posterior fields 10 by 15 cm., 52 Rx in 63 days. Daily dose 100 r, total 9,200 r. Grand total 5,700 mg. hr. and 9,200 r in 110 days. Eight months after beginning treatment, and four months after end of treatment there was diarrhea, bloody stool, and signs of partial obstruction. The obstruction was caused by a loop of sigmoid bound to bladder and rectum.

Pemberton³ reported a woman, aged 43 years, who had had menorrhagia for one year. She had had a laparotomy with bilateral salpingectomy seven years before. A small fibroid was felt in one cornu of the uterus. Rapid sections from the curettage showed endometrial dysplasia. Radium, 100 mg., with 0.5 mm. silver and 1 mm. brass was inserted into the uterine cavity for twelve hours. The patient was admitted to the hospital sixteen months later. There had been occasional attacks of pain and discomfort in the rectum. Five days before admission "something broke in the lower abdomen and there was fever and discharge." After no improvement in three weeks, a laparotomy was performed. A loop of sigmoid was densely adherent to the back of the fundus uteri, and there was an abscess containing 2 to 3 ounces of pus between them. The raw sur-

faces were sutured over and hysterectomy was performed. Their conclusion was that it was a mistake to insert radium into the uterus of a patient who had had a previous pelvic operation.

CASE REPORT

In the following patient the damage followed irradiation treatment for carcinoma of the fundus uteri. As these things usually go, there undoubtedly have been many more cases of bowel damage following irradiation treatment for carcinoma of the fundus that have not been reported. Also, probably there may be other reports in the literature which we have not encountered. Nevertheless, the rarity warrants reporting.

Although radium was given, the damage apparently followed the protracted courses of x-ray therapy, since at operation there was widespread involvement of the entire small bowel and other abdominal contents. It was also clinically difficult to differentiate between extensions intra-abdominally of carcinoma of the fundus and adhesions causing the patient's symptoms. As is well known, the extension of carcinoma of the cervix is into the broad ligaments and around the ureters. Many of these patients die from strangulation of the ureters, and at necropsy it is found that the carcinoma has involved the tissues within $1\frac{1}{2}$ to 2 inches of the cervix only. On the contrary, carcinoma of the fundus is notorious for extension into the general abdominal cavity, causing multiple masses, multiple foci of obstruction, liver deposits, etc.

CASE 1.—Mrs. M., aged 49 years, was seen for the first time July 28, 1944. Her menopause had been completed seven years previously. She was perfectly well until June, 1943 (six years). At this time she complained of spotting, and on one occasion suddenly passed large clots of blood. There was also fatigue and weakness. She was advised to have a dilatation and curettage for diagnosis and shortly was hospitalized for this purpose. The curettings showed adenocarcinoma of the fundus (July, 1943). Because of some doubt as to the cardiac reserve, operation was not done. She was given deep x-ray therapy, beginning Aug. 10, 1943. She received treatments daily for six weeks, ending in September, 1943. Then in February, 1944, radium was inserted into the uterus for one week. April 10, 1944, another deep x-ray therapy course of daily treatments for five or six weeks was instituted, ending May 16, 1944. She had not felt well since the end of this treatment. Diarrhea started in April, 1944. Soon the abdominal pain and cramps started. For the next two months, there was marked weight loss and great anorexia associated with abdominal discomfort and pain. For the next six weeks, that is since June 6, 1944, bowel movements were difficult, although for the next week constipation was somewhat less. The pain was rather generalized over the entire abdomen, but more marked in the left lower quadrant. When first seen at home, April 28, 1944, the patient presented an extreme clinical picture. She was very pale and pasty looking, lying very weakly in bed, unable to sit up, and was breathing very heavily. She was taken to Harper Hospital that night. She was quite dehydrated and anemic (hemoglobin 57 per cent, red blood cells 2,740,000, an irregular low-grade fever, and white blood cells 12,000). Abdomen showed extensive discoloration from x-ray therapy over both lower abdominal quadrants. There was some tenderness in the left lower quadrant. Pelvic examination was unsatisfactory, but the uterus was perhaps $1\frac{1}{2}$ to 2 times normal size, was not very mobile, and there was some tenderness in the left adnexal region. In the hospital, the anemia improved under treatment for dehydration and transfusions. The low-grade fever and pelvic tenderness disappeared under penicillin therapy. The hemoglobin rose to 69 per cent, with 3,140,000 red blood cells, 4,750 white blood cells, and her bowels moved more freely. She was discharged Aug. 7, 1944, with a diagnosis of carcinoma of the fundus uteri with peritoneal extension and metastases.

She made weekly or bi-weekly visits to the office for follow-up study. She felt better. Bowels moved somewhat more freely, and the pain in the left lower quadrant gradually subsided. At one time, the pain and pelvic tenderness increased, but following a short course of penicillin she felt improved. She continued to have backaches, and the red blood cells hovered around 3 million. Pelvic examination revealed the uterus gradually subsiding to relative normal size. However, she did not quite regain her strength.

About Nov. 1, 1944, pain somewhat like the original cramps started again. She felt tired, but usually had good bowel movements. She had gained weight, about fifteen pounds since treatment, but was still twenty pounds below her usual pre-illness weight. On Dec. 3, 1944, she was suddenly seized during the night with very severe abdominal cramps and vomiting. These continued during the night. She was again taken to Harper Hospital. Examination showed seizures of very severe abdominal cramps, coming in spasms associated with nausea. Bowels had not moved for twenty-four hours. Abdomen was not tense but during the seizures there seemed to be tenseness throughout. Seizures were very painful. This was an attack of intestinal obstruction. The Levin tube brought forth some foul-smelling intestinal contents. Miller-Abbott tube was then introduced, and it descended five or six inches past the jejunum. Bowels did not move for five or six days, then enemas became effectual and the patient felt better. X-ray examination with emphasis on the small bowel showed moderate dilatation of the small bowel loops, many of them filled with gas. The barium passed slowly beyond the upper jejunum and at the end of six hours barium was still in the upper small bowel. At the end of twenty-four hours, the film showed barium still distributed throughout the small bowel. There was some irregularity of the small bowel pattern in the pelvis. Although there was marked hypermotility of the barium meal with much stasis in the small bowel, some of the barium apparently passed into the large bowel and was seen in this twenty-four-hour film in the region of the cecum at the colon. X-ray diagnosis was incomplete small bowel obstruction. The Miller-Abbott tube was removed Dec. 12, 1944. Bowels then moved normally, she felt well, and since the obstruction was relieved she was discharged on Dec. 17, 1944. The diagnosis was intestinal obstruction. It was still uncertain whether this was due to metastatic deposits inside the abdomen or whether the obstruction was due to x-ray damage to the small bowel.

Another attack of violent cramps and constipation sent the patient to the hospital two weeks later (Dec. 29, 1944). However, within one or two days she was having normal bowel movements and no cramps, and she was again sent home on limited nonresidue diet. At this time the hemoglobin was 88 per cent and red blood cells 4,240,000. Evidently, she was not losing ground or becoming anemic.

She again felt well and bowels moved for two weeks but about Jan. 20, 1945, suddenly during the night, she had the old sharp abdominal pain. Pains came every five or ten minutes lasting all day. Some of these were "as if she were cut in half." She stated that if she "could have a real bowel movement," her troubles would end. She volunteered information that she had not had a normal evacuation "since she had had that old therapy in 1943 and 1944." Even when they did move, the evacuations were in small pieces and she always had to take oil or milk of magnesia. There had been no diarrhea since a few weeks following the last course of therapy. She continued to feel nauseated after eating. Examination, Jan. 26, 1945, revealed a soft abdomen with no definite abdominal tenderness. Because of the repeated bouts of small intestinal obstruction and the maintenance of her general health, it was decided that the period of observation should be ended. The probability was that the obstruction was due to adhesions and not necessarily extension of the malignancy. Exploratory operation was advised. This was done on Feb. 1, 1945. As the abdomen was entered, the fat seemed fibrous and thickened, the fascial layer was not clearly defined, and the muscle was a dark chocolate color. It appeared to be evidence of rather extensive previous x-ray therapy. The peritoneum was opened. The small intestine was thin and pale and the blood vessels were not very prominent. The uterus was normal in size. The bladder folds were somewhat adherent. Posteriorly, the sigmoid was adherent to the posterior surface of the uterus in the cul-de-sac. The adnexa were bound down low in the pelvis and were small and atrophic, the adhesions being quite dense. Lightly separating the sigmoid from the posterior wall of the uterus, a small nick was made in it. This was immediately sutured with three mattress sutures. Further exploration of the deep pelvis revealed a matting down of the adnexa posterior to the uterus. The adnexa were small, shriveled, and fibrous and seemed to show the effects of x-ray therapy.

The small bowel was then explored. The terminal ileum for about twelve inches was somewhat thicker than the upper region. At one point, about ten inches from the cecum, there was a dense adhesion binding the small bowel to the anterior right peritoneum far out toward the cecum. It seemed as if this was sufficient to cause kinking, which was responsible for the patient's symptoms. In the upper portion of the abdomen, the omentum in the region of the liver was also densely adherent to the undersurface of the liver and to the parietal peritoneum.

The whole picture was one of post-x-ray therapy damage with extensive changes, in the wall of the small bowel, pelvic organs, omentum, and peritoneum.

Convalescence was eminently satisfactory. Normal bowel evacuations started immediately. She was discharged on the seventh day. Since leaving the hospital, she has "felt like a different person." She takes mineral oil occasionally, once a week, whereas before it was necessary to take it every day. When last seen May 21, 1945, she had normal bowel movements (with occasional mineral oil, as stated). She has regained her strength, her appetite is excellent, she can do her own housework, and has gained twenty pounds since the operation. Examination showed a totally different looking individual, robust and healthy appearing. The abdomen was soft, and there was no tenderness. Pelvic examination was negative.

SUMMARY

A case is reported in which severe generalized small bowel damage, with intestinal obstruction due to adhesions, followed prolonged x-ray therapy for carcinoma of the fundus of the uterus.

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AN INTESTINAL SPUR-CRUSHING CLAMP

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CRUSHING the spur is an essential intermediate step in the Mikulicz series of operations frequently used for colon resection. This procedure destroys the assembled double medial wall of the two-barreled colostomy to the end that intestinal content may flow from the afferent limb directly into the efferent intestinal tube. Although any ordinary heavy hemostat may be used to destroy the partition through its entire length, this act is more effectively accomplished by clamps specially designed for the purpose. The most acceptable of such enterotribes have their jaws meet in parallel approximation. A thumb turnscrew or ratchet arrangement provides for a gradual and slow increase of pressure. Usually the crushing surfaces have grooves in their longitudinal or transverse direction to provide some nonslip quality when applied.

Two deficiencies of these standard enterotribes, however, detract from their correct performance. The instrument frequently slips off the thick intestinal septum unless it is immediately and severely tightened down. The result is a painful and disagreeable experience to the patient. The second fault is that the distal ends of the blades tend to spread apart; the consequent loss of applied force at that far point is the cause for failure to divide the spur at its lowermost and important level. Unquestionably, this failure to obliterate the spur entirely

makes it difficult or almost impossible to obtain an immediate and primary closure of the stoma of the colostomy at a later period.

For several years I have employed, with much satisfaction and sufficiently often, a parallel action type of enterotribe, made more helpful and efficient for severance of the intestinal spur by certain changes in the design of the biting surfaces. Both blades are provided with large, evenly spaced saw teeth which

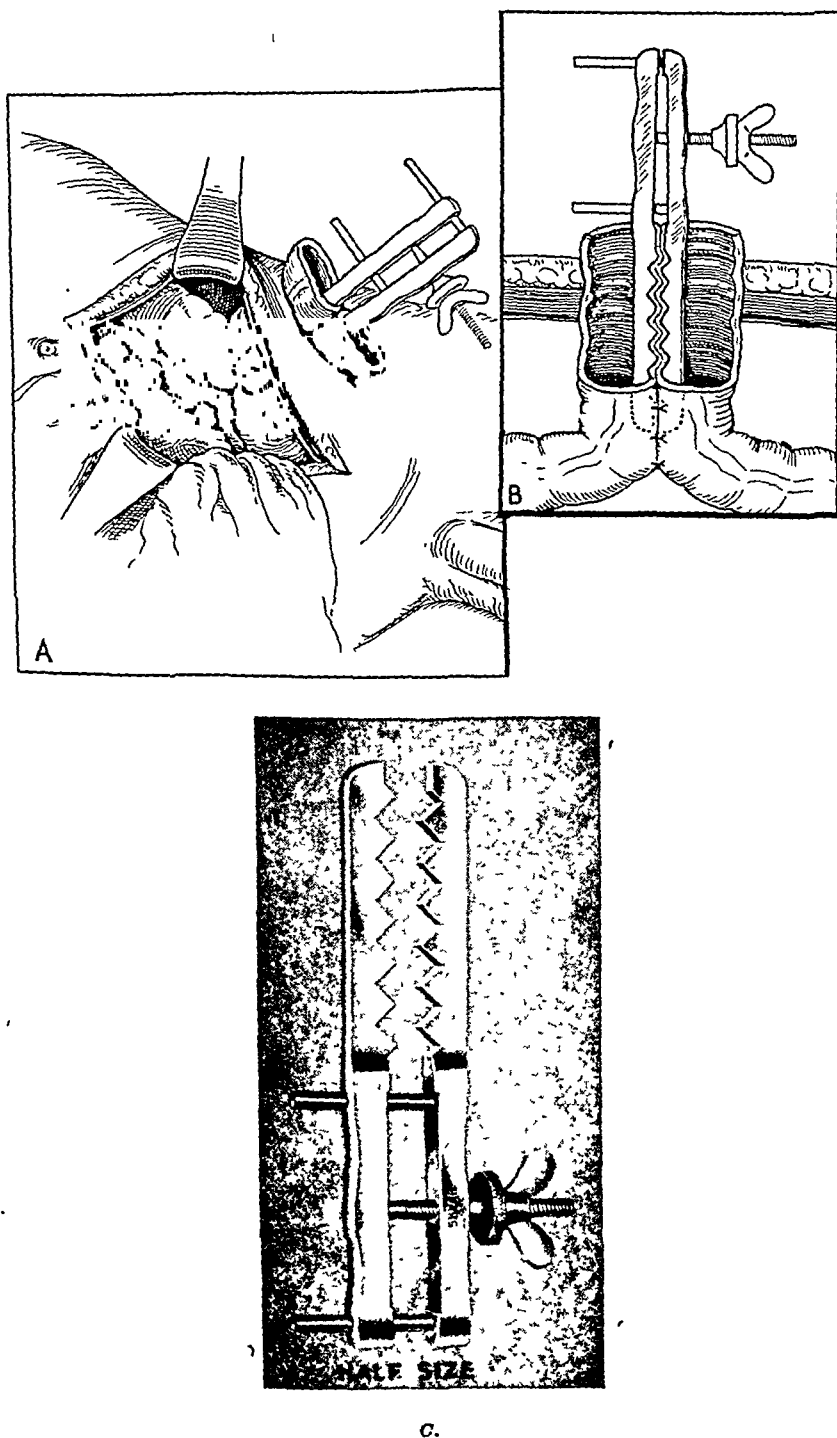


FIG. 1.—A, Showing the double-barreled colostomy and its relative position to the abdominal wall with spur clamp in position. B, Schematic cutout drawing showing the saw-tooth clamp applied to the double-walled partition of colostomy. C Photograph of clamp.

interdigitate with each other. Any slight pressure of the jaws presses and fixes the intestinal septum barrier at multiple points holding it firmly without slipping (Fig. 1 *A* and *B*). Continued pressure stretches segments of the gut over the corrugated surfaces of the blades, thus permitting a quicker division of the septum as the coaptating force is slowly applied. Since each angular digit member of the bite wedges firmly into a counternotech of its opposite companion, it forms a firm multilocking unit which does not allow any appreciable side slipping or end spread of the clamp.

It is helpful, before inserting the open clamp into the two barrels of the colostomy, to dilate those cylinders slightly with a gloved finger which has been coated with any ordinary emollient.

The instrument* as pictured (Fig. 1 *C*) is of stainless steel, with an over-all length of five and three-fourth inches; its crushing blades are three inches in length; the width of the blades one-fourth inch.

CLOSURE OF DUODENAL FISTULA

A NEW TECHNIQUE

MAJOR W. H. SNYDER, JR., LIEUTENANT COLONEL C. J. BERNE,
CAPTAIN H. I. RIDELL, AND CAPTAIN E. L. TURNER, MEDICAL
CORPS, ARMY OF THE UNITED STATES

ON THE afternoon of Jan. 7, 1945, a 29-year-old American soldier was flown from the forward area to our Evacuation Hospital in northern Burma. Two rifle bullets fired at close range had entered the anterior abdominal wall just to the left of the umbilicus and made their exit just to the right of the spinal column avulsing the posterior abdominal wall (Fig. 1) and lower chest, leaving a large ten-inch gaping wound through which blood was pouring from a ruptured kidney and torn renal pedicle. The injury had occurred one and one-half hours before entry. The patient was in profound shock from trauma and hemorrhage.

Blood and plasma were given and in less than one hour after entry, under ether anesthesia, the wound in the lateral wall was extended medially (Fig. 2) by a transverse incision. The adrenal gland and the upper two-thirds of the right kidney were pulpified. They were removed and the kidney pedicle ligated. A three-inch section of the ascending colon had been avulsed by the bullets. The remaining portion of the ascending colon and the hepatic flexure were mobilized and a double-barreled colostomy formed (Fig. 2). The colonic mesentery was used to fill the gap in the lateral abdominal wall. There was a jagged hole in the right lobe of the liver the size of two clenched fists. This was débrided and packed of necessity to stop the hemorrhage. The tenth, eleventh, and twelfth ribs had been shattered and the diaphragm was torn, producing a sucking wound of the chest. This was repaired by suturing the diaphragm to the lateral chest wall. The right portion of the abdominal cavity and the entire wound was contaminated by fecal material from the severed colon. Further

*The instrument is made by the Sklar Manufacturing Company, Long Island City, N. Y.
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Fig. 1.—Two bullets entered the anterior portion of the abdomen at close range. This shows the extensive posterior gaping wound shortly after débridement.

Fig. 2.—The wound consisted of nearly a hemisection of the body at the level of the first lumbar vertebra.



Fig. 3.—The tube on the right passes through a gastrostomy opening into the duodenum and was used for suction. The tube on the left passes into the duodenum and was used for feeding.

abdominal exploration revealed no pathology. The second portion of the duodenum had been exposed by the passage of the bullets, but no gross damage to the wall was visualized.

During the first few days the patient's condition was critical. Constant gastric suction was instituted. Fluid balance was maintained by the intravenous route (Fig. 8) and 200,000 units of penicillin per day were given intramuscularly for five days. On the eleventh day after the original surgery a

duodenal fistula developed. A Witzel jejunostomy was performed and a second tube was directed through a gastrostomy opening into the duodenum for constant suction and salvage of the duodenal fluid (Fig. 3). A second jejunostomy was necessary on the twenty-third day because the previous tube had accidentally become dislodged. On the twenty-fourth day it was possible to insert



Fig. 4.

Fig. 4.—T tube with elliptical piece of rubber inner tubing. A small hole in the center of the elliptical piece of inner tubing allows the long arm of the T tube to be passed through this opening.



Fig. 5.

Fig. 5.—T tube and elliptical piece of rubber tubing ready for insertion into the fistula.



Fig. 6.—T tube and elliptical piece of rubber tubing in place in the duodenum exposed in the depths of the wound

a T tube through the fistulous opening in the duodenum and, with the use of an elliptical piece of rubber inner tubing (Figs. 4 and 5), to form a nearly tight closure. Subsequent to this, normal feedings were possible. The wound was filling in satisfactorily, but lower partial thoracoplasty may be advisable to fill the defect in the lateral wall. It may be possible to effect final closure of the duodenal fistula by simple suture after reaction in the duodenal wall has entirely subsided.

DISCUSSION

Rapid transportation of the patient to the Evacuation Hospital by air, the availability of almost complete laboratory facilities, equipment, and drugs, the application of physiologic principles, early surgery, and good nursing care made it possible for us to evacuate this man in good condition to the General Hospital five weeks after surgery.

The combination of difficulties which were encountered in this case may not be duplicated frequently and yet the same general problems in postoperative management are present in many battle injuries. The physiologic principles and technical devices used in this case will be described with the hope that this information may be helpful to others.

Salt Balance (Fig. 7).—The recent work of Coller and associates¹ on salt intolerance seemed especially applicable in this case, as our patient had only one kidney and one adrenal gland following a right nephrectomy. During the first eight days, while the patient was on constant gastric suction and taking nothing by mouth, the total intake of saline was only 3,000 c.c. Until the recent emphasis on salt intolerance we would have considered this amount entirely inadequate² and yet in view of the satisfactory blood chlorides, blood CO₂ (Table I),

TABLE I. LABORATORY FINDINGS

DAYS	2	5	8	12	16	19	23	27
Sp. gr. blood	1.0605	1.057	1.0485	1.059	1.057	1.056	1.061	1.052
Sp. gr. plasma	1.028	1.030	1.0	1.0335	1.031	1.031	1.032	1.027
Hematocrit	47.5	40.5	24		40	38	45	35.5
Hemoglobin (Gm.)	14.5	13.7	9.9	13.5	13.5	12.9	15.2	12
		12.5	9.5					
R.B.C.	4.84	4.17	2.76	3.91	4.39	3.38	5.17	4.34
								3.62
W.B.C.	24,800	16,300	19,750	12,900	9,700	8,850		8,050
Blood chloride (mg.)			393	505	528	545	470	561
				482				
Blood CO ₂ (vol. %)			62		73	46		52
N.P.N. (mg. %)		102	44	72	59	84	70	40
Plasma protein (Gm.)	7.2	7.9	7.3	9.1	8.2	8.2	8.6	6.8
Urine albumin		1+	1+	1+	1+	1+	1+	Neg.
Urine sp. gr.			1.018	1.018	1.015	1.019	1.022	1.016
Urine chloride (mg. per liter)			3-4	0-1	0-1	2	0-1	6-7
								4

adequate urinary output (Fig. 8), and in view of the persistent albumin in the urine, high nonprotein nitrogen, reversed albumin globulin ratio, and low salt output in the urine³ we cannot but feel that this case adds some support to Coller's new concept of guarded control of salt intake.

From a study of Fig. 7 it appears that a fair quantity of salt was administered during the first eleven days. However, we wish to re-emphasize that all of this intake of salt came from blood and plasma (100 c.c. of plasma equals 0.6 Gm. of salt, and 100 c.c. of blood equals 0.5 Gm. of salt), with the exception of a total of only 3,000 c.c. of saline given in the first eight days. Unless the blood and plasma source of salt is recognized many patients with war injuries will postoperatively be overloaded with salt. Edema of the intestines and fluid collection in the abdomen can be easily mistaken for peritonitis.

After the development of the duodenal fistula the salt intake was greatly increased and was administered both through the jejunostomy and intravenously. Most of the fluids escaping from the duodenal fistula were returned through the jejunostomy so that salt which otherwise would have been lost in this way was utilized. Fig. 7 shows only the additional salt administered.

The fluid balance, which is related to the salt balance, is shown in Fig. 8. The tremendous amounts of fluid which were necessary to maintain a balance were in the main given through the jejunostomy after the eleventh day. In addition blood, plasma, and saline and glucose were given intravenously. On

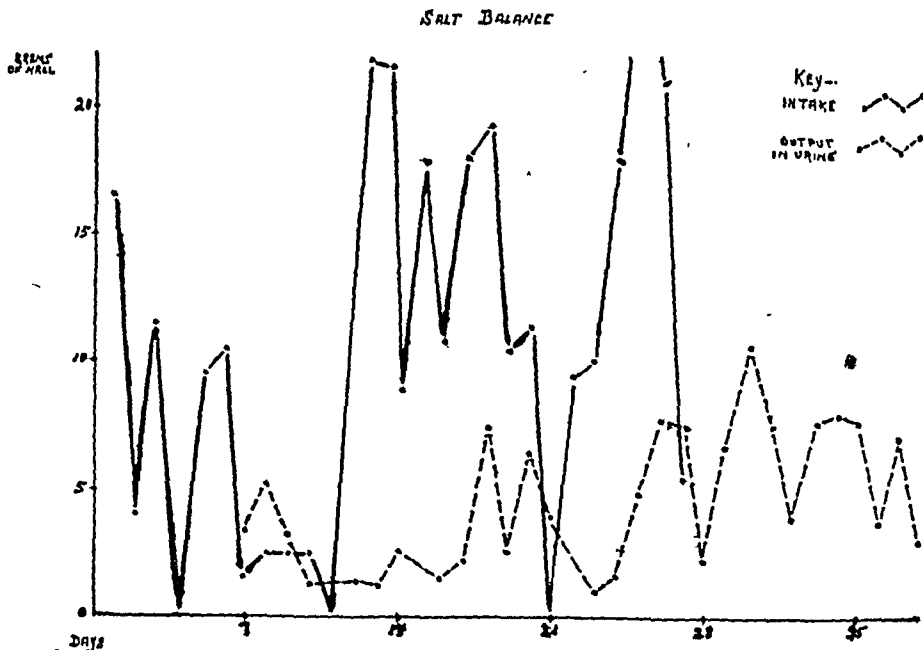


Fig. 7.—In calculating the intake of salt we considered each 100 c.c. of plasma equal to .6 Gm. of NaCl, each 100 c.c. of blood equal to .5 Gm. of NaCl, and each 100 c.c. of normal saline solution equal to .9 Gm. of NaCl; the output in the urine was determined according to a recent directive.²

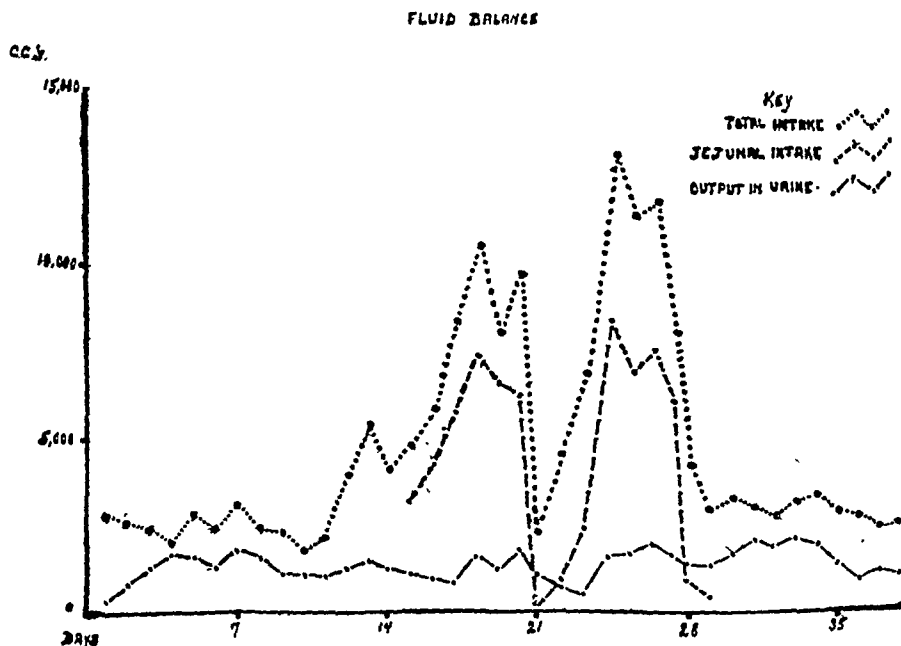


Fig. 8.—Total intake includes amount given by vein, mouth, and jejunum. Jejunal intake equals the total amount given through the jejunostomy.

some days the fluid intake through the jejunostomy reached nearly 9,000 c.c. of which nearly 5,000 c.c. were composed of bile, pancreatic and intestinal juices. We feel sure that the collection and return of this fluid through the jejunostomy was an important factor in this patient's recovery.

Protein Balance.—During the first eight days all protein (Fig. 9) was given intravenously in the form of blood and plasma.⁴ Subsequently, some protein was given by mouth. During this period while the loss through the duodenal fistula was great, the protein taken by mouth and excreted through the fistula was returned through the jejunostomy. In addition, a considerable amount of protein was administered in the form of an egg and milk mixture through the jejunostomy. It is obvious from Fig. 9 that the protein intake was not adequate, but attempts to increase the amount were thwarted by the development of intestinal disturbances. By the twenty-eighth postoperative day, the drainage from the duodenal fistula was controlled and subsequently all protein was administered by mouth. Supplementary intravenous administrations of Amigen⁵ would certainly have been desirable, but this was not available.

PROTEIN INTAKE

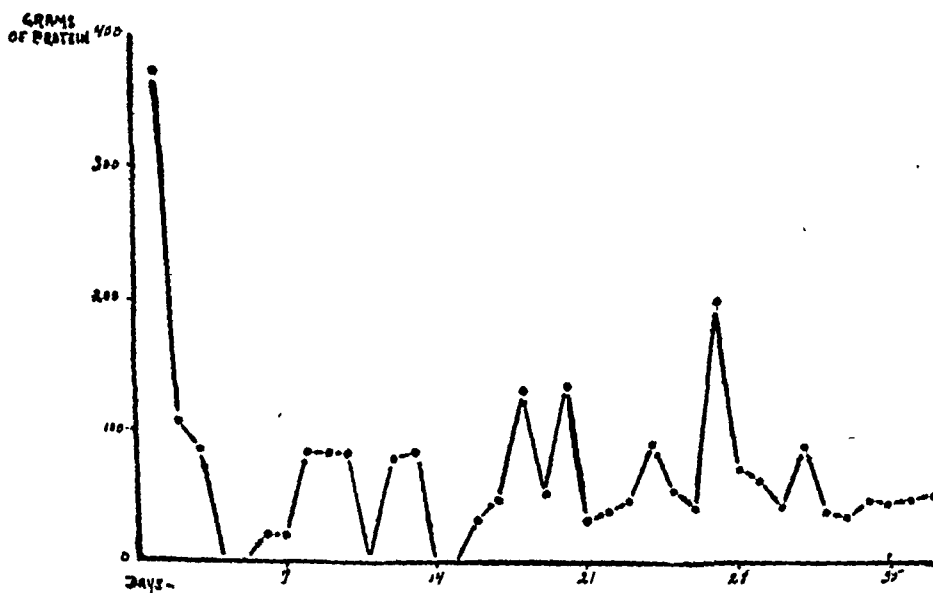


Fig. 9.—The amount of protein given this patient was calculated from the ingredients administered, that is, 100 c.c. of plasma equals 7 Gm. of protein, 100 c.c. of blood equals 18 Gm. of protein,⁴ 100 Gm. of powered milk equals 27 Gm. of protein; protein content of diet also added.

Collection of Duodenal Contents.—On the eleventh postoperative day bile and duodenal content appeared in the depths of the wound. Although no gross damage to the duodenum was evident at the time of the original surgery, the wall of the second portion had been traumatized by the bullet and a break in its continuity developed. For the first few days the loss of duodenal contents was minimal. On the thirteenth day a major duodenal fistula was present and the effects of this complication were evident in the patient's general condition. A jejunostomy was, therefore, performed for feeding purposes. The position of the gunshot wound on the posterior lateral wall made aspiration of the leaking duodenal fluids technically almost impossible. Repeated attempts⁶ to pass a Miller-Abbott tube was unsuccessful. In order to salvage as much of the duodenal contents as possible, a tube was inserted through a gastrostomy opening and directed into the duodenum (Fig. 3). Continuous aspiration was maintained by means of this tube. This procedure was fairly successful, but there was still considerable fluid lost. The duodenal opening had enlarged and could now be easily seen in the depths of the wound. Attempted suture was unsuccessful.

ful due to the edema of the surrounding duodenal wall. Finally a common duct T tube was inserted through the fistula and suction applied. Even though it was possible to return most of the duodenal drainage by means of the jejunostomy and in spite of additional forced jejunostomy feedings, the patient did not make satisfactory progress. After many other unsuccessful attempts to close the duodenal fistula an elliptical piece of rubber was fashioned from an old inner tube (Figs. 4 and 5) and a T tube threaded through a hole in its center. This assembly was then inserted through the fistula (Fig. 6). By tension on the T tube, pressure was made against the inner wall of the duodenum by the elliptical piece of rubber inner tubing, resulting in a nearly watertight closure of the fistula. This type of internal valve closure with a T tube and elliptical strip of rubber tubing has served its purpose. At least it has tided our patient over a crucial stage and the device may be applicable as a temporary measure in the closure of other duodenal fistulas, such as those occurring in accidental posterior wounds following nephrectomy.

SUMMARY

1. In large avulsing wounds of the posterior lateral abdominal wall the utilization of the mesentery of the colon may provide a satisfactory reconstruction.

2. With the loss of one kidney and adrenal gland plus severe abdominal trauma, limitations of salt intake according to Coller's new concept is apparently beneficial.

3. The temporary closure of a wound in the posterior lateral wall of the second portion of the duodenum may be effected by the use of a T tube and elliptical piece of rubber inner tubing.

4. The United States Army has provided facilities for extensive laboratory studies even in remote areas of Burma.

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A METHOD OF IMPLANTING THE PANCREATIC DUCT INTO THE JEJUNUM IN THE WHIPPLE OPERATION FOR CARCINOMA OF THE PANCREAS

CASE REPORT

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(From the Department of Surgery, University of Minnesota Hospitals)

A UNANIMITY of opinion does not yet exist concerning the necessity of the external secretion of the pancreas for the maintenance of a completely healthy nutritional state. Even a cursory appraisal of case reports, in which the radical operation for cure of carcinoma of the head of the pancreas has been performed without attempting to preserve this secretion, suggests that the nutritional effects may be quite variable. With some,¹⁻³ a very nearly normal existence is enjoyed; at other times, the patient's state is clearly an unsatisfactory one, unless a substitution therapy of lecithin, choline, or raw pancreas is provided to correct steatorrhea and other evidences of disturbed fat metabolism. To date, which case will tolerate deprivation of this juice has been an impossible prediction and, hence, presents a major therapeutic obstacle to all who favor ignoring this problem. Also, any procedure capable of reducing the incidence of external pancreatic fistula, a not sufficiently infrequent complication after ligation of the duct, should warrant additional consideration for itself. Finally, if the anastomotic method is simple, requires no special paraphernalia, and appears to yield consistent results, it would seem to merit trial and scrutiny by others at work in the field on this problem. For these reasons, the method of pancreatico-enterostomy devised and tried in the experimental laboratory in 1941 is reported here. At that time, I was studying intestinal absorption from Thirty loops of the duodenum, which required a segment as completely free as possible of biliary and pancreatic secretions. These experiments were designed for a long-time study. To insure, therefore, the best nutritional status, the biliary duct and main* pancreatic ducts were transplanted usually to the upper jejunum. Following this procedure, six animals remained in excellent health without steatorrhea or other evidence of abnormal fat or protein metabolism, while maintained on a fare of hospital scraps, dog biscuits, and occasional supplements of horse meat. When sacrificed at from six to ten months after surgery, the pancreas in all cases was a normal pale yellow-pink color and possessed a pliable soft consistency. In several instances, a short patulous segment of duct at the site of transplantation could be identified. Neither the liver nor the pancreas was sectioned but appeared grossly normal. Because of its apparent success, this method was applied to a patient on Aug. 5, 1943, during the course of a resection for carcinoma of the head of the pancreas.

CASE REPORT

A. W. (University Hospital No. 733594), a white man aged 70 years, first noticed the onset of painless jaundice about two or three weeks prior to his initial hospital visit on

The researches upon which this presentation is based were supported by a grant from the Graduate School of the University of Minnesota.

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*Any additional ducts were divided, ligated, and separated from the duodenal wall by a slip of omentum.

July 7, 1943. It had increased steadily in intensity during this interval, and had not been associated with any pruritis or physical incapacity. Stools had been clay colored, the urine dark for about two weeks. When the patient was admitted upon the medical service, the positive physical findings were jaundice with a greenish cast, an enlarged gall bladder, and a reducible, indirect left inguinal hernia. Quantitative analysis of a four-day stool indicated 3 mg. of urobilinogen per day. The total serum bilirubin was 8.7 mg. per cent with 6.5 mg. per cent appearing in the first minute. X-ray examination of the stomach and duodenum was reported to be normal. The diagnosis was carcinomatous biliary obstruction probably due to carcinoma of the head of the pancreas. The patient insisted upon returning to his home before the operation, was admitted to the surgical service on July 25, 1943, and operated upon Aug. 5, 1943. During this interval he was prepared with a high protein, carbohydrate, caloric, low-fat diet, fortified with liberal quantities of thiamine, cevitamic acid, and vitamin K. Anesthesia was secured with a nupercaine spinal and endotracheal inhalation of cyclopropane. A partial gastric resection, complete duodenectomy, resection of the head of the pancreas, resection of proximal 16 cm. of the jejunum, cholecystojejunostomy, catheter choledochostomy, catheter pancreaticojejunostomy, and gastrojejunostomy were performed. At the time of the exploration through a transverse incision, a mass involving the distal portion of the common bile duct and head of the pancreas was felt and deemed to be carcinomatous. The greater and lesser curvatures of the stomach were devascularized and it was divided approximately in the mid-portion. The common duct was then transected and the duodenum freed from its avascular attachments to the inferior vena cava and transverse mesocolon as well as from the blood supply through the mesenteric vessels. The pancreas was sectioned caudad to the neck, isolating the main pancreatic duct with preservation of a short extra glandular segment. Pursuance of the dissection in the vicinity of the splenic, portal, and superior mesenteric vessels ultimately allowed removal of the specimen in a single mass. The fundus of the gallbladder was then anastomosed to the end of the jejunum, a catheter choledochostomy was made, and a terminolateral gastrojejunostomy was effected about 45 cm. from the proximal cut end of the small bowel.* About midway between these two points, the pancreatic duct was implanted. Two sutures of fine silk were so placed as to hold patulous this thin-walled structure. An 8 cm. piece of No. 12 size, two-holed catheter was then inserted for a distance of from 1 to 2 cm. This was accomplished by essentially the same plan as had been employed during pancreatic duct implantations carried out in the experimental laboratory. In Fig. 1† illustrations of the operative procedure detail the operative steps in a very satisfactory manner. The procedure is as follows.

DESCRIPTION OF METHOD FOR IMPLANTING PANCREATIC DUCT

A two-holed catheter is selected, which is somewhat larger in diameter than the conduit to be intubated. An 8 cm. segment of this is stretched over an obturator (a Keith skin needle serves very well) impaled at a point on the catheter wall slightly eccentric to the tip and away from the lateral opening in the catheter. With increasing elongation of the catheter over this rigid probe, there is an appreciable decrease in its transverse diameter. This condition is then maintained by clamping all structures firmly with a sturdy hemostat at some distance from the tip. An oblique section is now cut from the tube, care being taken to place this line of excision distal to the tented wall of the catheter. The stylet bearing this prepared catheter is then slipped a short distance into the duct, facilitated by slight traction on the previously placed guy sutures. Release of the hemostat then allows the catheter to resume its originally greater diameter, thus snugly filling the cannulated duct. To insure this coaptation between catheter and duct, a fine catgut or silk ligature can be pulled down gently onto the duct wall in its extra glandular portion. Usually, the seal is satisfactory without this, and pancreatic secretions drip freely in a short while from the free end of the catheter. With fine interrupted silk sutures the serosa of the jejunum is then approximated to the fibrous elements of the pancreatic capsule along its posterior, superior, and inferior margins. A fine puncture is made through all coats of the jejunum at the site selected from the anastomoses. This is effected easily by the pointed end of a Keith or some other cutting edge needle. No formal incision is necessary. The firm substance of the catheter readily dilates the merest point of entrance through the tough submucosal coat. Such a close fit then assures a nice apposition between the several layers of

*The operative plan is essentially that described by Dennis.⁴

†Drawn by Miss Daisy Stilwell.

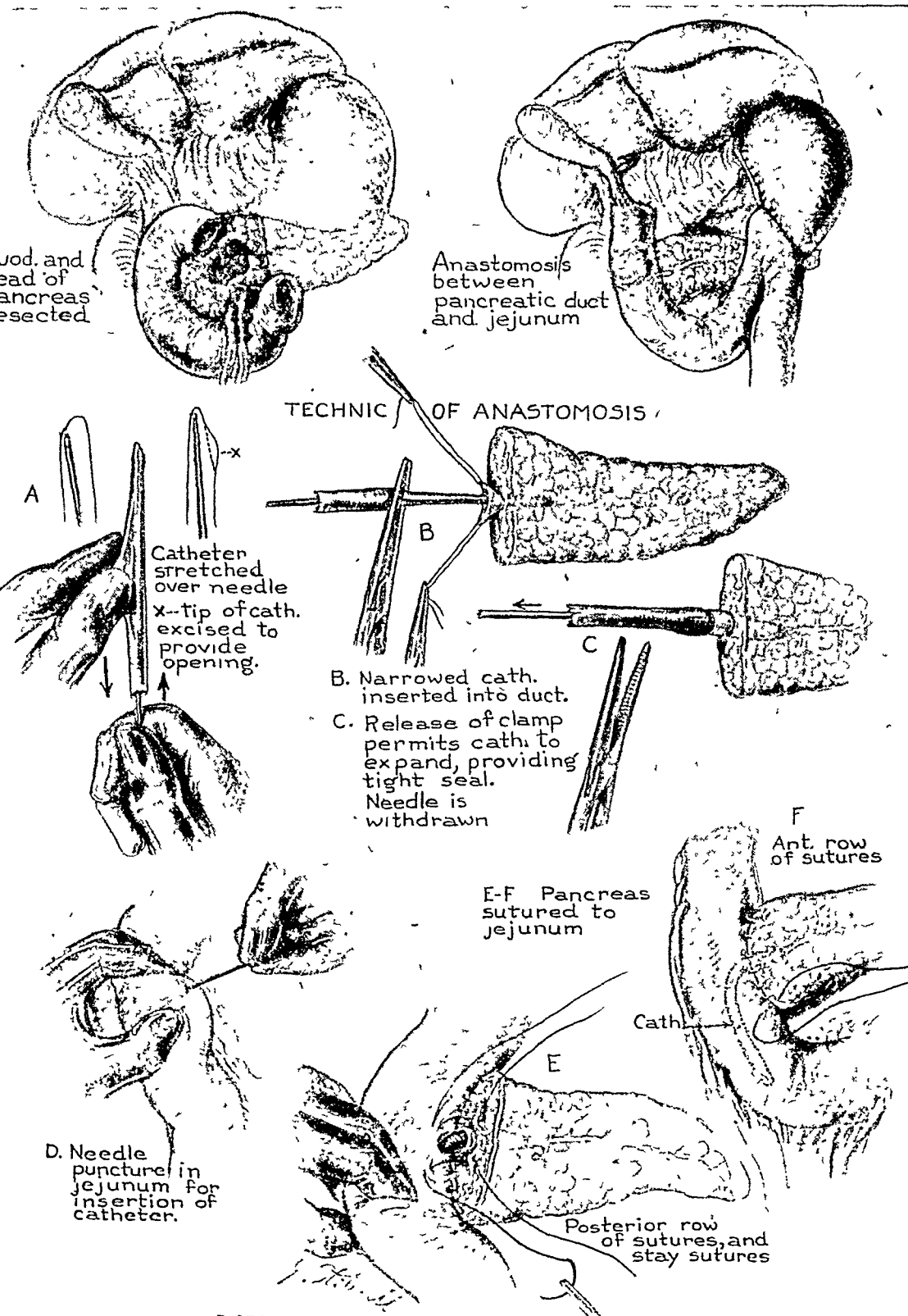


Fig. 1.—The two drawings at the top indicate approximately the site involved by malignancy and diagram the visceral configuration in the completed procedure, based on the Dennis' plan of operation for carcinoma of the head of the pancreas. The technique of implanting the pancreatic duct into the jejunum is shown in sketches A to F.

the enteric wall and the pancreatic duct. Two fine silk stitches are placed between the connective tissue adjacent to the duct and the bowel wall next to the puncture site. Tying these ligatures as the catheter and duct are threaded through the small aperture into the gut lumen firmly approximates the pancreas to the bowel and reduces any tendency for the duct to escape from its intramural and intraluminal position. The serosa of the jejunum is then tacked with fine silk sutures to the capsule of the pancreas about the remainder of its periphery, namely, the anterior aspect.

Drains were placed down to this area and the site of the catheter choledochostomy, and were brought out through separately placed wounds. The abdomen was closed in layers with fine silk sutures. The patient was slightly febrile until the removal of the indwelling duodenal tube on the sixth day. No drainage of moment occurred and therefore the drains were removed at about this time also. The pancreatic catheter was passed some time after the tenth postoperative day. There was a gradual decline in the patient's jaundice following a temporary increase postoperatively. The stools, although virtually bile-free through failure of the cholecystojejunostomy to function properly, were never foamy or diarrheic, nor did they contain excess fat or protein. No studies were made of the intestinal contents for tryptic activity. Recovery was protracted several weeks by bouts of gastric retention and delayed emptying, which had virtually disappeared when a barium study was secured on Sept. 7, 1943. The patient returned for a change of the choledochostomy tube on Oct. 1, 1943, and stated bile was now present in stools when the tube was clamped. His health was fair at the time with some gain in weight since his discharge. There was no diarrhea, and he was constipated if anything. His health began to fail in January, 1944, and he died shortly thereafter of what clinically seemed to be a recurrence, since no autopsy was secured.

DISCUSSION

The convalescence was unnecessarily complicated and prolonged; he was not discharged until the thirty-nine postoperative day because of two technical blunders. A cholecysto-enterostomy was made instead of the more satisfactory end-to-end anastomosis between the common duct and the small bowel. Whipple⁵ has called attention to the hazard and undesirability of the former procedure. Fortunately, a catheter had been placed in the end of the common duct as a safety vent in case the cholecystojejunostomy failed to function adequately. This one did not for many weeks; during this period the bile drained to the exterior chiefly via the catheter choledochostomy. A choledochojejunostomy alone, or protected by a catheter placed into the common duct through the cystic duct after removal of the gallbladder, it should be emphasized, is the procedure of choice. The second technical error was related to threading the jejunum for the gastric anastomosis up the bed occupied by the duodenum, and, hence, behind the superior mesenteric vessels. An antecolic positioning of the loop would have avoided the troublesome episode of gastric retention and vomiting. By buttressing the cut end of the pancreas with the peritoneal coat of the bowel wall, any oozing of pancreatic secretion from the cut surface is somewhat limited. However, diversion of the bulk of these strongly proteolytic enzymes to a site several centimeters removed where they may occasion no real damage, probably is the major factor in averting a pancreatic fistula. My colleague, Clarence Dennis, of the surgical staff of the University of Minnesota Hospitals, since has employed essentially this plan for implanting the pancreatic duct in three additional cases. There has been no instance of pancreatic fistula.

SUMMARY

1. A simple effective method for implanting the pancreatic duct is described.
2. The case record of a patient upon whom this method was used is reported in detail. Three additional instances of its utilization are cited.

3. Some of the technical features in the operation of radical resection of the head of the pancreas are discussed.

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SUBTOTAL AND PALLIATIVE GASTRECTOMY FOR CHRONIC GASTRIC ULCER

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THE pathologic findings in acute and chronic gastric or duodenal ulcer are essentially identical. Both have a definite life cycle characterized by periods of exacerbations and remissions. Clinically, the symptomatology produced is often so similar that a differential diagnosis cannot be made. As a rule, both respond to adequate medical treatment. Gastroduodenal ulceration becomes a surgical problem only when certain complications arise which do not respond to medical therapy. The indications for operative intervention have been fairly well crystallized. The ulcer becomes an urgent surgical problem when an acute perforation occurs and in very exceptional cases when an exsanguinating hemorrhage persists. The chronic ulcer ultimately concerns the surgeon when the symptoms become refractory to medical treatment, when hemorrhages are recurrent, and when a pyloric obstruction becomes intractable to conservative measures. However, an ulcerating lesion in the stomach presents an additional problem which does not apply to duodenal ulcer—the possibility that it may be malignant.

It is this differentiation between a benign and carcinomatous ulcer which may offer insurmountable difficulties even when the best diagnostic facilities are available. Klingenstein,¹ in 1936, presented before the New York Surgical Society a series of 165 cases of chronic gastric ulcer in which operation was done between 1925 and 1935. In 20 per cent of these cases, a preoperative diagnosis of carcinoma had been made by the roentgenologist, and in 12 per cent an ulcer, previously thought to be benign, was proved to be malignant at operation. While it is true that a benign ulcer rarely undergoes malignant degeneration, carcinoma cells were found in two of a series of 141 pathologic examinations of chronic gastric ulcer made by Klein.² Recently, Yarnis and Colp³ reported three cases of benign ulcer in which an unsuspected independent gastric carcinoma existed simultaneously. Furthermore, experience has shown that the temporary disappearance of an ulcer niche, following a course of medical therapy, is not positive proof that a carcinoma does not exist. These facts illustrate the uncertainties in making an accurate diagnosis of any gastric

lesion, and if they were constantly borne in mind, there undoubtedly would be less hesitancy on the part of the medical profession in subjecting a patient with a chronic ulcer niche to radical surgery.

This communication deals with a review of forty-two consecutive patients with chronic gastric ulcer who were admitted to the surgical ward service of the Mount Sinai Hospital during a six-year period from July 1, 1937, to June 30, 1943:

HISTORY

This series was composed of four women and thirty-eight men. Thirty-four patients were between the ages of 40 and 60 years; the youngest patient was 21 years, the oldest was 64. The duration of the disease varied from several months to forty years, and was characterized by acute episodes of varying intensity, usually responding to some type of medical therapy. Ten patients had one or more recurrent gastric hemorrhages. Two experienced previous gastric perforations which had been sutured several years before their present admissions. Ten patients had been hospitalized at one time or another for the medical treatment of an ulcer. All patients with one exception complained of epigastric pain which had hitherto been intermittent and was now becoming more persistent and severe. Occasionally a history of back pain suggested the possibility that the ulcer had penetrated the pancreas. In some, nausea, vomiting, and anorexia, which had been only occasional, became more pronounced, and many patients volunteered the information that the vomitus often contained food eaten the previous day. Loss of weight had occurred in one-half the patients.

Patients were admitted to the surgical service only when the pain was becoming more severe despite adequate treatment, when an intractable pyloric stenosis was evident, when hemorrhages had become recurrent, and when the presence of a carcinoma was suspected.

PHYSICAL EXAMINATION AND LABORATORY DATA

Physical examination in many instances disclosed evidences of recent weight loss and dehydration. Epigastric tenderness was present in a few patients. As a rule the Rehfuess test meal disclosed an increase above the normal values in the free and total acidity but the reports of gastric analyses were interpreted with circumspection. It should be universally known by the present time that the findings of a hyperacidity in the presence of an ulcerating lesion do not rule out the possibility of a carcinoma, and that a benign ulcer may exist in the presence of a low free hydrochloric acid. For example, in a series of 140 patients studied by one of us (R. C.), the presence of a gastric carcinoma was proved by operation, yet the test meals in over one-half showed free hydrochloric acid values ranging from 20 to 60 millimoles per liter and combined acidity of from 40 to 113 millimoles per liter. In fifty patients the gastric analyses disclosed the absence of free hydrochloric acid although the combined acidity varied from 10 to 80 millimoles per liter. The entire question of the pre- and postoperative acidities in our material is being studied and will be presented in detail elsewhere. An absolute achlorhydria was present in only twelve cases. In the present series of forty-two proved benign ulcers, twenty-five patients had an elevated acidity and fifteen patients had normal acid figures. In two cases the acid studies had been lost.

The barium meal examination was of inestimable value in the differential diagnosis of benign and malignant lesions of the stomach, for the characteristic x-ray findings would often indicate the presence of a benign gastric ulcer or

point unmistakably to a malignant one. In this series of forty-two benign gastric ulcers, the roentgenologist reported three cases as highly suggestive of neoplasm. In six cases, an additional deformity of the duodenal bulb was reported and operation revealed either a healed duodenal scar or active ulcer, as well as the gastric lesion. In three cases, in which a duodenal deformity alone was reported, a gastric ulcer which had been unsuspected was found at operation. The amount of barium retention revealed by gastric roentgenograms is often misleading. The quantity of residue obtained by aspiration through a stomach tube after a twelve-hour fast is a more reliable index of gastric dilatation secondary to pylorospasm or organic obstruction.

Borderline cases in which a definite diagnosis cannot be made are often clarified by gastroscopy, which was performed on twenty-seven patients. In one patient the examination was unsatisfactory, and in four patients the gastric ulcer could not be visualized gastroscopically although it was demonstrated roentgenographically. In the twenty-two other cases, the gastroscopist visualized definite gastric ulcerations, five of which he pronounced malignant, but which were subsequently proved benign. However, it must be realized that certain areas of the stomach cannot be seen with the Schindler gastroscope and that the value of this examination is partly dependent upon the skill of the gastroscopist. Both roentgenologic and gastroscopic examinations are indispensable in the diagnosis of gastric lesions; but even the use of both methods will not eliminate entirely the possibilities of errors in diagnosis.

A complete blood count and chemical examination of the blood (urea, chlorides, CO_2 combining power, and plasma proteins) were always made. Anemia, hypoproteinemia, and alkalosis were not infrequently encountered in those patients who had been vomiting or bleeding prior to admission. For example, J. K. (No. 457919) entered the hospital after many weeks of pain, vomiting, and tarry stools. The hemoglobin was 120 per cent, the plasma proteins 5.9 Gm. per cent, the blood urea 35 mg. per cent, and the CO_2 combining power 84.5 vol. per cent, evidences of recent bleeding, dehydration, and alkalosis.

PREOPERATIVE PREPARATION

Many of these ward patients, when admitted, were in poor general condition. The systemic effects of the intractable pain, inadequate nutrition, vomiting, and hemorrhage were reflected in loss of weight, dehydration, anemia, and certain chemical imbalances, all of which needed correction prior to operation.

All patients were given an initial period of complete bed rest. Pain was controlled with mild sedatives, aluminum hydroxide, atropine, the frequent feedings of bland foods, and occasionally the milk and amphotojel drip as advocated by Winkelstein, Cornell, and Hollander.⁴ Adequate hydration was assured by the daily administration of 1,500 c.c. of saline solution and glucose. If, because of pyloric obstruction, vomiting had been a prominent symptom, the amount of daily intravenous fluids was increased to 4,000 c.c. and a gastric lavage with hot saline solution was performed twice daily through a large gastric tube. This latter procedure often allayed the spasm or reduced the inflammatory reaction about an edematous pylorus to such a degree that gastroduodenal continuity was restored, with the subsequent cessation of vomiting, diminution of pain, and a marked improvement in the general condition of the patient. Adequate vitamins were administered. Repeated transfusions of whole blood were given to anemic patients until the hemoglobin was elevated to 80 per cent. Whenever possible, regardless of age, treatment is conservative for the majority of the patients with massive hemorrhage, operation being deferred until they

have fully recuperated from the systemic effects of their blood loss. Only one patient was operated upon during acute hemorrhage. This was done because it was believed that the patient was suffering from a bleeding carcinoma of the stomach, not a bleeding ulcer.

CASE 1 (No. 440605).—W. H., a 60-year-old man, was admitted to the Mount Sinai Hospital, May 18, 1939, complaining of epigastric pain of one year's duration. During this time the pain had become increasingly severe, and recently had been accompanied by nausea, vomiting, a loss of fifteen pounds, and attacks of weakness. For four weeks the patient had had tarry stools daily. The past history was noncontributory except for the fact that the patient had been a moderately heavy drinker.

Physical examination disclosed a chronically ill, very pale, elderly man. There was moderate peripheral sclerosis; the blood pressure was 100 systolic and 70 diastolic. There was moderate epigastric tenderness.

The hemoglobin was 27 per cent, the red blood count was 1,590,000, and white blood count 15,000. The blood urea was 11 mg. per cent, blood sugar 105 mg. per cent, CO₂ combining power 53.8 vol. per cent, total protein 4.7 Gm. per cent. The urine was negative. The stools were tarry and were markedly positive to the guaiac test for blood. The electrocardiogram was normal. The test meal revealed free acid 50 millimoles, combined 66 millimoles. X-ray disclosed the presence of a penetrating ulcer at the re-entrant angle of the stomach. Gastrosocopy revealed a deep lesser curvature ulcer which was very suggestive of carcinoma.

The patient was put at complete bed rest. He was fed the Muelengracht diet and was given adequate vitamins and sedatives. Repeated transfusions of whole blood were administered until the hemoglobin was elevated to 68 per cent. However, because of the persistence of the pain, the guaiac positive stools, and the gastroscopic appearance of the lesion, it was felt that the patient was suffering from a neoplasm of the stomach, and therefore exploration was indicated despite the recent hemorrhage.

Accordingly, on June 3, 1939, laparotomy was performed under ethylene ether anesthesia. A definite benign gastric ulcer quite adherent to the pancreas was found and a subtotal gastrectomy and posterior terminolateral gastrojejunostomy of the Hofmeister type was performed.

The patient made an uneventful recovery and was discharged on the fifteenth day.

If a high protein diet was ineffective in correcting a hypoproteinemia, plasma and amino acids in adequate amounts were administered parenterally. None of the patients in this series required a preliminary jejunostomy for alimentation. Desoxycorticosterone was used preoperatively in eight patients but as no definite benefits were noted in these or in other cases its use was discontinued. The sulfonamides were not used preoperatively.

ANESTHESIA AND OPERATION

Almost every type and combination of anesthesia have been used. Twenty-five of the patients received general inhalation anesthetics and seventeen were given continuous spinal anesthesia. At present, continuous spinal anesthesia combined with sodium pentothal intravenously is considered the method of choice as it provided the best relaxation and exposure, with a minimal amount of retraction.

The abdomen was routinely explored through a median epigastric incision extending from the ensiform cartilage to the umbilicus. The pathologic findings encountered were varied in so far as the location, extent, and depth of the lesions were concerned. For conveniences of description, the location of the ulcers may be divided into those which occupy the pyloric area (which was found only once), those situated in the antrum, those located at or near the re-entrant angle on the posterior wall of the stomach, and those in the cardia. Many of the posterior wall ulcers were of the penetrating variety and were attached to or had eroded into the pancreas. Ulcerating lesions larger than

2.5 cm. in diameter are not necessarily malignant. This is well illustrated in Case 2.

CASE 2 (No. 499998).—F. B., a 57-year-old man, was first admitted to the Mount Sinai Hospital Jan. 5, 1943, complaining of progressive weakness during the previous six months, and postprandial vomiting for the previous six weeks. He had lost fourteen pounds and had suffered from pronounced anorexia. He had never had any pain or noticed tarry stools.

Physical examination disclosed a pale, emaciated man. The chest was emphysematous. No masses or tenderness was present in the abdomen.

The hemoglobin was 57 per cent. The blood sugar was 80 mg. per cent, urea 12 mg. per cent, CO_2 combining power 60.2 vol. per cent, chlorides 575 mg. per cent, and the proteins 7.5 Gm. per cent. The urine was negative and the stool contained occult blood. The test meal disclosed a free acid of 60 and a combined acid of 80 millimoles. The electrocardiogram was normal. X-ray of the stomach (Fig. 1) revealed a huge ulcer and a large ulcer pocket on the lesser curvature, above the re-entrant angle. Gastroscopy disclosed a large ulcerating lesion involving the entire posterior wall of the corpus of the stomach. The distal edge was just proximal to the angularis, and the proximal edge appeared to be 3 cm. from the cardia. The lesion was thought to be a large ulcerating carcinoma.



Fig. 1.—Arrows depict enormous extent of ulcer.

The patient was prepared in the usual fashion with transfusions, gastric lavages, vitamins, intravenous fluids, and rest. Exploration was done, Jan. 25, 1943, through the usual midpigastic incision. A large hard mass with an ulcer crater was felt on the posterior wall and lesser curvature of the stomach. It was firmly attached, over a broad area, to the pancreas, which was subsequently found to form the ulcer base. A retrograde gastrectomy was performed. The necrotic surface of the pancreas was not excised, but was covered with sulfanilamide. The area was drained by a rubber dam which was brought out through a right subcostal stab incision. Gastrointestinal continuity was re-established by a typical retrocolic gastrojejunostomy. A complementary jejunostomy for alimentation was performed. The wound was closed with through-and-through sutures.

The pathologic report of the specimen was large chronic peptic ulcer of the stomach, measuring 4.5 by 2 cm.

The patient made an uneventful recovery.

A few penetrating ulcers of the lesser curvature were found which evidently had previously perforated and were sealed off by the liver and in one instance by the gall bladder.

In a few patients in whom a preoperative diagnosis of pyloric obstruction had been made, an ulcer on the lesser curvature of the stomach and a normal pylorus were found at operation. In these cases a reflex pylorospasm or a disturbance of the peristaltic wave must be assumed.

The surgery of chronic gastric ulcer has run the gamut of technical procedures, many of which have now been discarded. Gastroenterostomy with or without local excision has not been found to be an entirely satisfactory procedure. While it is true that gastric acidity was diminished due to the neutralizing effects of the alkaline jejunal regurgitation, the symptoms were rarely permanently relieved and the recurrence of either a gastric ulcer or the formation of the more serious gastrojejunal ulcer has been frequent. Sleeve resections, because of the resultant hourglass deformities leading to physiologic dysfunctions, are no longer done. The operation of choice for chronic gastric ulcer in this clinic is subtotal gastrectomy of the Hofmeister type. This procedure has distinct advantages. It radically removes the pylorus and most of the ulcer-bearing area of the stomach, and if the resected specimen should contain malignant cells, the chances of cure are naturally materially enhanced. In addition, it assures relief of symptoms in practically all cases and freedom from future recurrent ulcerations. A follow-up study of Rehfuess test meals in patients subjected to partial gastrectomy for gastric ulcer⁵ has demonstrated an achlorhydria in over 88 per cent of the cases and probably because of this, recurrent gastric and gastrojejunal ulcers have not been observed. It is our belief that gastroenterostomy should never be done for *gastric* ulcer. If the lesion is so massive that resection appears impossible, then a preliminary jejunostomy for alimentation⁶ seems a logical procedure. Following this, the stomach is put at partial physiologic rest and the ulcer should regress so in size that a partial gastrectomy may be performed several weeks later with comparative ease and safety.

The operative procedure may present technical difficulties, especially in penetrating ulcers. The method of resection differs somewhat from that described for duodenal ulcer,⁷ for it is usually done in a retrograde fashion. The duodenum is transected first, so that the stomach may be gradually mobilized and reflected to the left, affording better exposure of the posterior surface of the stomach, an area frequently involved by ulceration. The technique which is followed at the present time will be described only briefly. The right gastric and right gastroepiploic arteries are ligated just distal to the pylorus, at which point the duodenum, which is usually mobile, is transected. The distal duodenum is closed with a chromic catgut suture of the Connell type and reinforced by a continuous linen Lembert suture. The duodenal stump is then buried against the head of the pancreas with a continuous plain catgut suture. There was usually very little difficulty in securing an adequate closure of the duodenum unless it was the seat of previous or active ulceration. However, if there was any doubt as to the competence of the suture line and a dehiscence was a possibility, the stump was drained with a rubber dam introduced through a right subcostal stab incision. This was done in nine instances. The gastrocolic omentum was then divided transversely toward the left between artery clamps applied below and parallel to the vascular epiploic arch, and the left gastroepiploic artery was ligated high on the greater curvature. The stomach was then carefully reflected to the left, exposing its posterior surface. Any adhesions which were present in the lesser omental sac were carefully divided, constant watch being made for any distortion of the middle colic artery. Occasionally

the stomach was firmly glued to the pancreas by a posterior penetrating ulcer, and separation could be accomplished only by sharp dissection.

In high lying ulcers, in order to mobilize the stomach more freely so that the lesion could be excised, it became necessary to ligate the left gastric artery close to its origin from the celiac axis. Originally, the part of stomach proximal to the ulcer was divided between rubber covered clamps unless the extent of the resection made their application impossible. During the past two years we have transected the stomach between a double line of clips laid down by the DePetz sewing machine and have found that this could be done even if the resection was made close to the esophagus. Following resection, gastrointestinal continuity was restored by an isoperistaltic terminolateral gastrojejunostomy of the Hofmeister type. In the first seventeen cases, a terminolateral anastomosis was made posterior to the colon. We have now discarded the posterior retrocolic type of gastrojejunostomy, having been impressed with the simplicity and the technical advantages of restoring gastrointestinal continuity *anterior* to the colon using a short proximal loop of jejunum about six inches long. Furthermore, we have noted no differences between this and the posterior anastomosis in either the immediate postoperative period or in the follow-up observation of patients. In the beginning of this series, the Murphy button was used in seven patients to restore gastrointestinal continuity in those instances in which, because of a high resection, a short proximal gastric segment remained. With added experience, the suture technique of anastomosis has been found feasible in all types of gastric resection and therefore the use of the Murphy button has been practically eliminated. Enteroenterostomy, which was thought to be necessary in high resections, has been discarded. It was performed only once in this series.

In nine cases in which either a very high gastric resection had been performed, or in which a marked preoperative dilatation of the stomach increased the possibility of postoperative gastric atony, a complementary jejunostomy for alimentation was done. This procedure and its advantages have been adequately described elsewhere.

Although subtotal gastrectomy with the removal of the ulcer is undoubtedly the procedure of choice, there were six cases in which the antrum and pylorus were removed, but the ulcer was left in situ. The lesion in four cases was a penetrating ulcer high on the lesser curvature, and in two cases the ulcers were juxta-esophageal in location. The general physical condition in four of the patients was so poor that an excessively high resection necessary to remove the ulcer would have been extremely hazardous. In the two patients with juxta-esophageal ulcers, a total gastrectomy would have been necessary if the ulcers were to be removed. For this type of case, Madlener⁸ in 1923 first suggested pylorectomy without removal of the ulcer. Flörcken⁹ subsequently removed the pylorus and as much of the antrum as possible, calling the procedure "palliative gastric resection." This procedure has not had wide application. It has one major disadvantage—the lesion which is not removed may possibly be carcinomatous. In adjudging the merits of this procedure, one must remember that removal of the antrum and pylorus of *patients suffering from gastric ulcer* almost always results in an anacidity, and that recurrent gastric or gastrojejunal ulcers under these conditions are almost unknown. In our limited experience, residual gastric ulcers apparently heal after palliative gastrectomy and recurrences have not been noted clinically, gastroscopically, or roentgenologically. Two of these cases have now been followed more than seven years. It therefore seems difficult to ascribe the disappearance of these lesions as an involutionary

stage in the life cycle of an ulcer. The subject of palliative gastrectomy for gastric ulcer will be discussed in detail in a subsequent communication.

The median epigastric incision was routinely closed with heavy silk sutures taken through all the layers of the abdominal wall. The advantages of this type of closure are that it is extremely rapid and that evisceration almost never occurs. It is unfortunately accompanied by an appreciable percentage of post-operative hernias. For this reason, interrupted steel wire sutures embracing the peritoneum, muscle, and fascia are now being used in addition to silk.

POSTOPERATIVE COURSE AND COMPLICATIONS

Postoperatively, a Levin tube was left indwelling, and an intravenous infusion of saline and glucose solution, which was given throughout the operation, was continued. If there had been moderate blood loss or any degree of shock, the patient was given blood, plasma, or both. Adequate sedation was administered. Oral fluids were allowed within twenty-four hours after operation. Sulfonamides were administered only when there was a specific indication as, for example, pneumonia.

The Levin tube was removed about the third day, and was passed again twelve hours later. If there was evidence of gastric retention, the tube was either left indwelling again for a two-day period, or was passed every twelve hours and the stomach completely emptied. The patients were encouraged to move about in bed. The sutures were removed in twelve days, at which time most patients were permitted out of bed.

Fourteen patients developed pulmonary lesions, most of which were atelectatic bronchopneumonias. This complication was rendered much less serious by the use of sulfonamides. If evidences of massive atelectasis or a marked accumulation of bronchial mucus was present, a bronchoscopy was rapidly done, and a mucous plug or the diffusely distributed mucus was removed. Recovery following this procedure, which was usually performed in the patient's bed, was prompt and very dramatic.

Two patients developed transient attacks of auricular fibrillation, and another sustained a coronary artery thrombosis with rapidly ensuing heart failure, pulmonary edema, and death.

There were two cases of gastric ileus, one of which was severe. The possibility of this had been anticipated and a complementary jejunostomy for alimentation had been done at the time of the original operation. In the other patient, the gastric atony was mild and subsided with conservative therapy.

A duodenal dehiscence occurred in three instances among the nine patients in whom drainage was carried out. One of these terminated fatally. While drainage does not always afford protection from the consequences of duodenal leak, it often prevents a fatal peritonitis or subphrenic abscess.

CAUSES OF DEATH

In this series of forty-two consecutive gastrectomies for gastric ulcer there were two deaths. One occurred following a subtotal gastrectomy, one following a palliative gastrectomy.

CASE 3 (No. 505682).—M. W., a 54-year-old woman, a known diabetic, entered the hospital, May 20, 1943, for the relief of abdominal pain of four years' duration. Ten years prior to admission she had had a cholecystectomy. She had been treated at various clinics for arthritis of the spine without relief. More recently she had noticed a few tarry stools, weight loss of eight pounds, occasional vomiting, and anorexia.

Physical examination disclosed an elderly appearing woman, exhibiting evidences of marked arteriosclerosis. There was tenderness in the midepigastrium and a well-healed right upper quadrant scar was noted. The liver was just palpable.

The hemoglobin was 63 per cent. Blood urea was 12 mg. per cent; blood sugar was 220 mg. per cent. The urine contained 1 per cent sugar. The stools contained occult blood on some occasions. The free gastric acidity was 60 millimoles, combined 76 millimoles. Gastrointestinal x-ray picture (made just before admission to the hospital) disclosed a penetrating lesion of the lesser curvature of the stomach. The electrocardiogram disclosed changes indicative of myocardial damage with previous coronary occlusion (posterior wall infarction).

The patient was treated medically for five weeks without improvement in her condition. The diabetes was controlled with diet and insulin. A preoperative diagnosis of carcinoma of the stomach was made. Exploration was performed through a median epigastric incision. There were many adhesions binding the duodenum and stomach to the undersurface of the liver. A huge ulcer was found on the lesser curvature of the stomach extending down from the re-entrant angle to the duodenum. The duodenum was stenotic and fibrotic and was the seat of an acute ulcer. The duodenal mobilization and closure were extremely difficult, and because the line of suture appeared insecure, the area was drained with a rubber dam made to emerge through a right subcostal stab incision. A subtotal gastrectomy with an antecolic terminolateral gastrojejunostomy and complementary jejunostomy for alimentation were performed.

The pathologic report of the specimen was chronic peptic ulcer of the stomach; duodenal ulcer; duodenum showing acute and chronic inflammation throughout the wall.

Postoperatively the patient did not do well. The temperature almost immediately rose to 105.6° F. and bile appeared along the rubber dam drain within a few hours. The abdomen became tender and rigid, the pulse rapid, and the blood pressure barely obtainable. Despite all forms of supportive therapy the patient died thirty-six hours after operation.

Post-mortem examination (No. 12543) disclosed a generalized peritonitis, due to a Welch bacillus, originating from a duodenal dehiscence.

CASE 4 (No. 416478).—J. G., a 58-year-old man, was re-admitted to the hospital, Nov. 10, 1937, complaining of abdominal pain of one year's duration. He had been treated five months previously for a known gastric ulcer. He improved with medical therapy and was discharged. However, he continued to lose weight and strength, the pain recurred and became progressively more severe, and vomiting began to occur with increasing frequency.

Examination disclosed a chronically ill man, showing evidences of recent weight loss and severe arteriosclerosis. There was slight tenderness in the epigastrium.

The hemoglobin was 83 per cent; urine was negative. The Rehfuess test meal showed a free acid of 70 millimoles and a total acid of 84 millimoles. Gastrointestinal x-ray showed a penetrating gastric ulcer about one inch in diameter on the posterior wall near the lesser curvature in the lower part of the fundus. Gastroscopy disclosed a punched-out ulcer high on the lesser curvature. The electrocardiogram disclosed occasional extrasystoles.

The patient was treated medically but his pain continued and it was finally felt that surgical intervention was imperative.

At operation an ulcer about two inches in diameter was found on the lesser curvature just below the esophagus. It was penetrating into the pancreas. There was evidence of a healed duodenal ulcer. It was felt that removal of the gastric ulcer would entail a total gastrectomy which was not indicated. Accordingly, a palliative partial gastrectomy was performed, leaving the ulcer in situ. The resected specimen after excision measured 9 cm. along the lesser curvature and 14 cm. along the greater curvature. Gastrointestinal continuity was restored by a retrocolic isoperistaltic gastrojejunostomy of the Hofmeister type.

The first postoperative morning the temperature was 100° F., pulse 100, tongue moist, abdomen soft. Later that day, however, the patient suddenly developed acute pulmonary edema, together with marked shock. The pulse rose to 190 and the blood pressure fell to 64/40. The patient exhibited no evidences of bleeding. He was placed in an oxygen tent, a phlebotomy performed, 50 per cent glucose administered intravenously, and morphine and atropine were given by hypodermic injection. Despite energetic therapy, the patient died two hours after the onset of the attack. The medical consultant who saw the patient felt that the incident represented an acute coronary artery thrombosis with left ventricular failure.

A post-mortem examination could not be obtained.

SUMMARY

A series of forty-two consecutive ward patients suffering with chronic gastric ulcer, treated surgically, is presented.

The chronicity of the history is stressed and the indications for surgical intervention are discussed.

The difficulties in the interpretation of the acid figures, the roentgenologic and gastroscopic findings as aids in the differential diagnosis between benign ulcers and ulcerating carcinomas are emphasized.

A plan of preoperative preparation is detailed.

The technique of subtotal gastrectomy which was used in thirty-six cases and palliative gastric resection which was employed in six patients is briefly outlined.

Postoperative care and management of the complications are described.

The two fatalities in these forty-two cases are outlined.

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THE HYPOCHLOREMIC STATE IN SURGICAL PATIENTS

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COLLER and his associates¹ have made a very important contribution to the postoperative care of surgical patients by revising their "clinical rule"² for the administration of salt solution. They felt that because of the relatively high incidence of "salt intolerance" following general anesthesia, salt solution should not be given the day of operation or on the first two postoperative days. The fluid requirements should be met with glucose in distilled water. They stated that the experience of years regarding the toxicity of isotonic sodium chloride has been forgotten. Trout³ over thirty years ago was quoted, "Even we surgeons know of the wonderful improvement in some patients with nephritis when placed on a salt-free diet, and all of us realize there is a transient renal irritation or possibly nephritis following the majority of anesthetics and infections." Collier and his associates also believed that great care must be used in administer-

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ing isotonic salt and Ringer's solution to patients who are hypoproteinemic, anemic, acidotic, or oliguric. Patients who tolerate salt poorly after operation are classified into three groups of predominant and fairly distinctive symptom and sign complexes. They recommended that the correction of uncompensated extracellular fluid deficiency states be made upon the basis of physiologic response to test doses of salt, rather than on the basis of the plasma chloride, the CO_2 combining power, the nonprotein nitrogen, plasma protein, or the hemoglobin levels.

I am in complete agreement with the need for extreme caution in the administration of salt as just discussed, but I wish to issue the emphatic warning that severe hypochloremic states may occur when patients are on a restricted salt intake. If active therapy (with saline solution) is not instituted in these cases, serious results may ensue. I wish to review briefly the manifestations of hypochloremia and attempt to establish criteria for the administration of salt in these patients who so frequently have a complicating abnormal but varying loss of salt (for example, from bile fistula).

Clinical Manifestations.—The onset of clinical hypochloremia is very insidious; the manifestations are similar to those of salt edema. Unless attention is paid to the extremely low blood chloride reading, and the possibility of the hypochloremic state is appreciated by studies of the clinical picture, salt may be withheld entirely instead of being given in large quantities. The most important diagnostic lead is obtained by realizing that a clinical state has been present when large amounts of electrolytes and chlorides have been lost without being compensated (for example, bile fistula, vomiting, high intestinal fistula, etc.). The clinical picture presents itself rather abruptly in the acute cases, as one of shock (blood chlorides below 300 mg. per cent). The skin is cold and clammy and the patient complains of extreme weakness. The pulse and blood pressure are usually unobtainable. Within forty-eight hours the urinary output has acutely decreased to 100 c.c. or less for twenty-four hours, with a corresponding rise in the nonprotein nitrogen. The body temperature is characteristically subnormal and in the neighborhood of 97°F . The blood chlorides are extremely low. A wrong diagnosis may lead to an early fatality due to the use of temporizing procedures or that utilized in the general therapy of shock. Hypochloremia which has progressed to the point of producing symptoms is an acute emergency and unless several thousand cubic centimeters of physiologic saline solution (containing 54 to 72 Gm. of salt) are given parenterally within twenty-four hours, it is unlikely that the patient will recover. It is obviously a fatal mistake to confuse such a case with one of salt edema which is easily done except for the presence of *edema* in the latter instance; in salt intoxication, a diffuse and pronounced dependent edema is rarely absent. An additional differential point is that, as a general rule, in hypochloremia the urine does not reveal casts, albumin, red cells, etc.

The clinical cases to be presented differ as to the mechanism of the chloride loss. The first case, as presented in detail in the Case Reports, concerned a 23-year-old girl with extensive granulating areas following a burn which involved 35 per cent of the body surface. Her anemic and hypoproteinemic state was adequately corrected with whole blood and plasma. However, we failed to appreciate the fact that huge quantities of chlorides and other electrolytes could be lost through the extensive granulating areas, that is until a picture of acute prostration and impending shock presented itself with a blood chloride reading of 327 mg. per cent. Ten thousand cubic centimeters of parenteral fluids containing 81 Gm. of salt were needed to elevate the blood chloride reading to

445 mg. per cent on the following day (normal 450 to 500 mg. per cent). The amount of salt given here is considerably more than that which would be given by the Coller "clinical rule," and perhaps was more than was actually needed; nevertheless, the clinical response was immediate and ideal. Hypochloremia in the second case was produced by excessive loss of chlorides through vomiting. The high intestinal obstruction was caused by a carcinoma of the distal end of the stomach. In the third and most interesting case the patient developed hypochloremia because of cholorrhea through a persistent external biliary fistula created when the common bile duct was opened to drain a suppurative cholangitis; a carcinoma of the ampulla of Vater produced the biliary obstruction. This patient presented the most acute picture of the hypochloremic state and was found early one morning in a state of extreme prostration and severe surgical shock. The patient's blood chloride reading at this time was 270 mg. per cent. Approximately 6,000 c.c. of fluids containing 54 Gm. of salt were needed to restore the blood chloride reading to normal. A daily maintenance dose of 40 to 50 Gm. of salt were required to keep the patient from relapsing

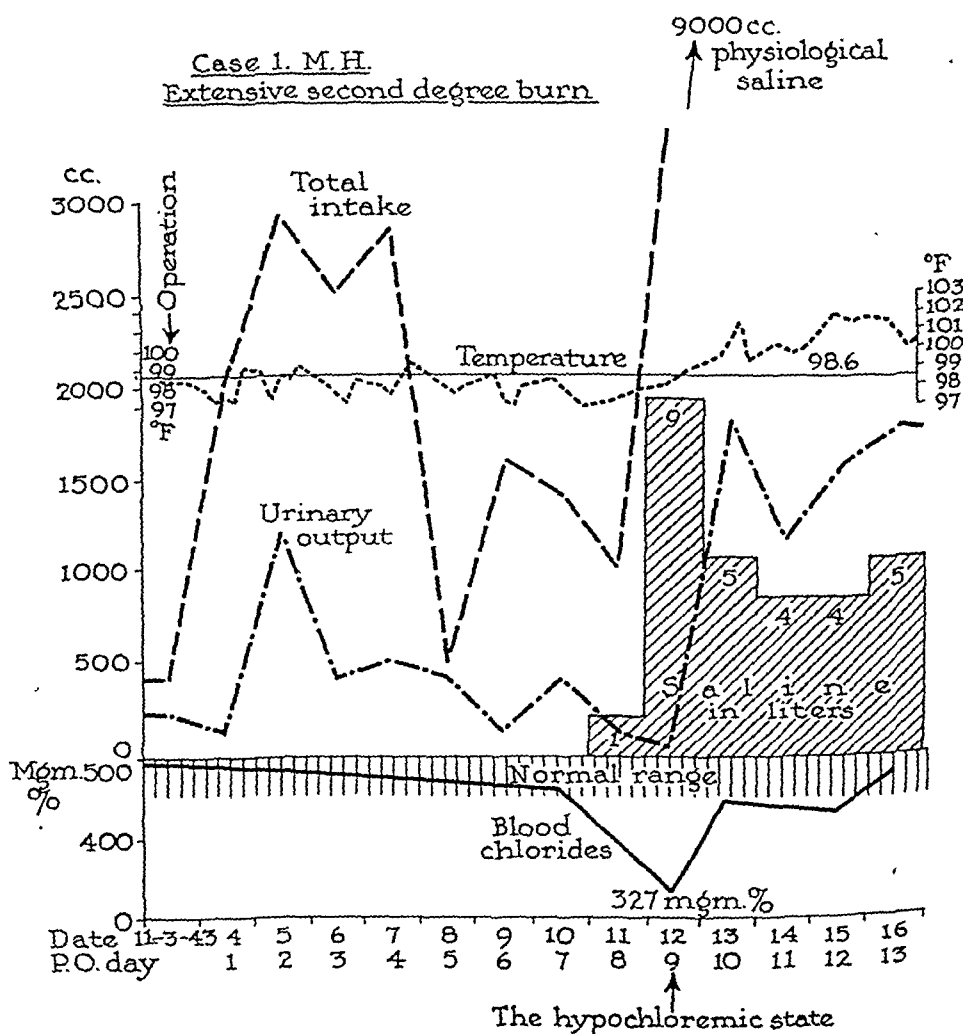


Fig. 1.—Postoperative course of extensive degree burn showing the subnormal temperature and decreased urinary out-put as acute hypochloremic state was approached on ninth postoperative day. The blood chloride at this point was 327 mg. per cent. The miraculous response after intensive salt therapy on the ninth postoperative day is shown by the increased urinary out-put from 50 to 1,850 c.c. during the next twenty-four hours, and a rise of the subnormal temperature to above normal. The blood chloride level required four to five days before it returned to normal limits in spite of the large amount of salt given to the patient.

into the hypochloremic state because of the excessive amount lost through the external biliary fistula. The output of bile approximated 3,000 c.c. daily. The chloride content of the liver bile averaged 740 mg. per cent (normal reading for liver bile 580 to 650 mg. per cent). The chloride content of this patient's bile was slightly above the normal average. The large amount of bile lost daily with its high percentage of sodium chloride obviously contributed greatly to the several recurrences of the hypochloremic state in this patient. A fourth case of painless progressive icterus due to a carcinoma of the common hepatic bile duct is very similar to the third case except for the absence of a complicating suppurative cholangitis. This patient also needed a very high daily maintenance dose of salt to compensate for that lost by the bile fistula.

CASE REPORTS

CASE 1 (No. 91038).—M. H., a 23-year-old white woman, entered the Research and Educational Hospital, Sept. 24, 1943, with extensive second and third degree burns involving both arms, chest, and neck. The granulating infected areas involved 30 to 35 per cent of the body surface. Early contractural scar deformities were present in the neck and over the shoulder and elbow joints. The burn followed the explosion of a kerosene stove nine weeks previously. After the patient's blood chemistry and hematologic determinations had been corrected, the granulating areas were grafted at ten-day intervals. On the eighth postoperative day following the fifth skin-grafting operation, the patient developed an acute hypochloremic state with a blood chloride reading of 327 mg. per cent. Her essential complaint in the first eight postoperative days had been mild crampy abdominal pain, apathy, anorexia, excessive thirst, extreme weakness, and vomiting of small amounts of bile-stained fluid with moderate abdominal distention. At first it was thought that the patient had an acute mechanical intestinal obstruction or possibly a salt intoxication. However, a flat x-ray film of the abdomen was characteristic of a paralytic ileus as dilated loops were noted throughout both the large and small bowel and a very rapid response was obtained with intensive salt therapy. Previously the usual conservative treatment of abdominal distention had been of no avail and the dramatic therapeutic response was not obtained until massive salt treatment was instituted parenterally. The very low blood chloride reading of 327 mg. per cent indicated the necessity of intensive salt therapy. The onset of the acute hypochloremic state on the eighth postoperative day presented itself as a picture of shock and prostration and was accompanied by a subnormal temperature of 97° F., a cold clammy skin, drowsiness and oliguria of 50 c.c. during the past twenty-four hours. The patient's blood chlorides were elevated to 446 mg. per cent within twenty-four hours by the administration of 9,000 c.c. of physiologic saline solution subcutaneously. The urinary output which amounted to 50 c.c. during the previous twenty-four hour period responded very readily to this therapy. The next twenty-four hour urinary output was 1,820 c.c. The nonprotein nitrogen dropped from 55.7 to 34 during the same period. The patient made an uneventful recovery thereafter, being given a maintenance dose of 36 Gm. of salt daily for several days to prevent any relapse.

CASE 2 (No. 95666).—L. C., a 65-year-old Negro man, entered the Research and Educational Hospital Aug. 18, 1944, complaining of vomiting small amounts of sour fluid after every meal for the past nine weeks. In addition, nausea, anorexia, and heartburn were prominent symptoms. He had lost nine pounds of weight during the ten days prior to entrance and was extremely weak when admitted to the surgical ward. At this time the abdomen was moderately distended and he complained of intractable crampy abdominal pain. Gastric aspiration yielded 1,200 c.c. of greenish-brown fluid on the day of entrance, but with no relief of the crampy abdominal pain. Laboratory examination revealed no free hydrochloric acid and 40 degrees of total acid. On the second hospital day the patient complained of extreme weakness. While waiting on a stretcher in the x-ray department for an x-ray picture to be made, he complained of symptoms of collapse. He was returned to bed immediately; upon examination he was very cyanotic, cold, clammy, and obviously in shock. The usual treatment of shock failed; the patient died within three hours. The blood chloride reading on the day of death was 272 mg. per cent. A clinical diagnosis of hypochloremia was not made and the blood chemistry determinations were not available until after death. Urinalysis revealed only a trace of albumin and the nonprotein nitrogen reading was 112 mg. per cent. The subnormal temperature of 98° F. obtained on admission dropped to 97° F. the following morning where it remained until death occurred thirty-six hours later. Post-mortem examina-

tion disclosed a carcinoma of the pylorus with chronic high intestinal obstruction complicated by an aspiration bronchopneumonia. The patient died less than forty-eight hours after entrance. No doubt the bronchopneumonia was an important contributing factor in this patient's death, but we are willing to admit that prompt recognition and treatment of his hypochloremia might have saved him.

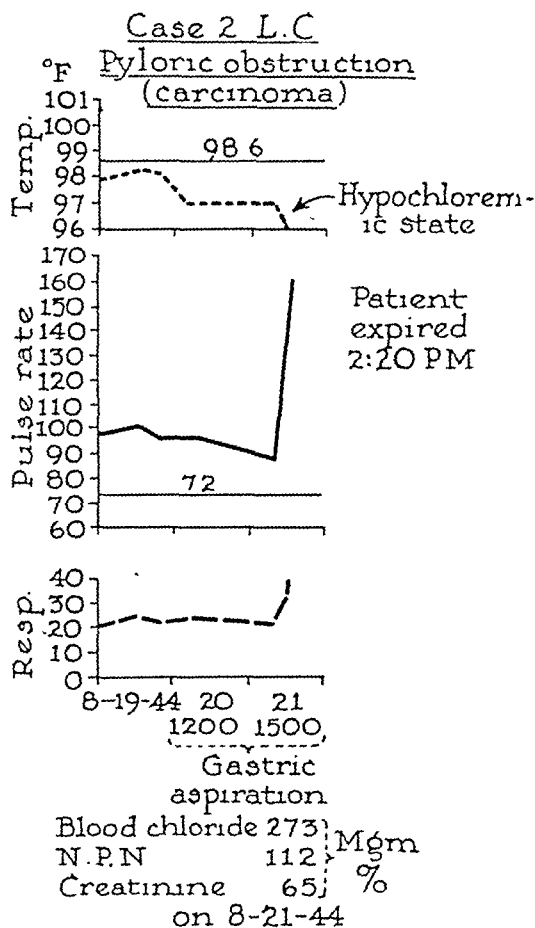


Fig. 2.—Patient sustained a tremendous loss of blood chlorides by vomiting small amounts over long period of time. He entered the hospital in hypochloremic state which was not recognized clinically. Due to his extreme weakness which was characteristic of the acute hypochloremic state, he developed aspiration bronchopneumonia and died within several hours. Blood chlorides at this time were 273 mg. per cent, with an extrarenal azotemia and a non-protein nitrogen level of 112 mg. per cent.

CASE 3 (No. 82396).—F. S., a 56-year-old white man, entered the Research and Educational Hospital April 14, 1942, complaining of intermittent chills and fever for the past two or three years. These attacks had become worse during the past six weeks and had been accompanied by extreme weakness and fatigue, pain in the right loin, and migrating body pains. Physical findings were essentially negative except for questionable icterus, and a large liver. He developed chills and a septic type of fever with increase of the icterus and a white blood count of 17,000. Exploratory laparotomy was performed April 22, 1942. The gall bladder was distended but not thickened. Aspiration of a common bile duct of normal size disclosed thin bile but no pus. However, numerous gram-positive cocci and gram-negative rods were found on stained smear. The head of the pancreas felt thickened but a positive diagnosis of carcinoma could not be made. The common bile duct was opened for drainage because of the numerous bacteria present. No stones were found. T-tube drainage was used with remarkable curative effect on the septic course. The patient's postoperative course was uneventful except for mild crampy abdominal pain, moderate distention, and a profusely draining external biliary fistula. On the sixth postoperative day, at morning rounds, the patient was found in obvious shock. His skin was cold and clammy and he complained of extreme weakness and apathy. The patient's pulse and blood pressure were unobtainable and rectal temperature reading was 97° F., at which level it remained for several days thereafter. Blood chloride determination obtained at this time was 270 mg. per cent. The chloride content

of the bile drainage was 740 mg. per cent. The total amount of bile drainage from the T tube the day before the acute hypochloremic state developed was 3,700 c.c. with a total of 12,200 c.c. during the previous five days. The daily urinary output dropped from 3,000 c.c. to 600 during the previous forty-eight hours. Six thousand cubic centimeters of physiologic saline solution containing 54 Gm. of salt were given parenterally in the first twenty-four hours. The following five days 36 Gm. of salt were given daily in conjunction with intravenous fluids, glucose, and adrenal cortical extract. The patient responded very well after the intensive salt therapy of the first twenty-four hours. The first blood chloride reading taken five days after the onset of the hypochloremic state was 447 mg. per cent (normal 450 to 500 mg. per cent). The patient had received approximately 200 Gm. of salt since the onset of the acute collapse five days before. On June 18, 1942, the patient again relapsed into a hypochloremic state with a blood chloride reading of 330 mg. per cent and complained of extreme weakness and apathy. This relapse was much less severe than the first attack three weeks previous. Oral salt in the amount of 5 Gm. daily supplemented by 18 Gm. intravenously maintained his blood chlorides within normal limits thereafter. He was discharged on June 27, 1942, with a diagnosis of chronic pancreatitis of the stenosing type.

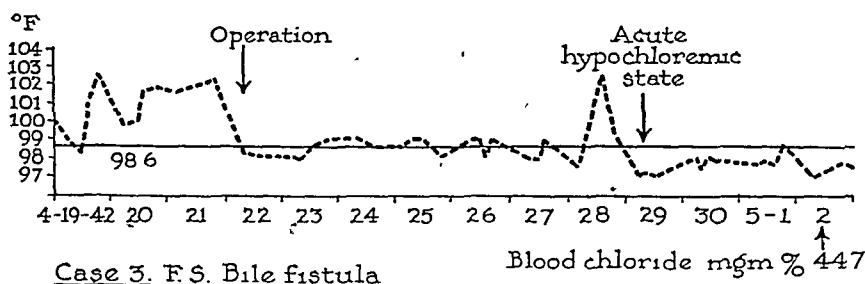


Fig. 3.—Postoperative temperature chart of patient with a carcinoma of the ampulla of Vater. Loss of chlorides was extreme through the external biliary fistula produced at operation. The acute hypochloremic state developed gradually and is characterized by the gradual development of a subnormal temperature which reached 97° F. during the acute hypochloremic state on April 29, 1942. The blood chlorides three days later were 447 mg. per cent; on the morning of the acute hypochloremic state the blood chlorides were 272 mg. per cent.

Approximately one month later, on July 16, 1942, the patient re-entered the hospital with another relapse into the hypochloremic state. The blood chloride reading at this time was 383 mg. per cent. The previous week had been very sultry with the temperature in the nineties. The patient's external biliary fistula was still draining profusely. After the blood chlorides had been balanced, exploratory laparotomy revealed a large tumor mass involving the porta hepatis with metastatic nodules in the liver. Biopsy disclosed a metastatic duct carcinoma of the pancreas or bile ducts, Grade III. The patient died Oct. 5, 1942, approximately five weeks after the last operation.

CASE 4.—W. D., a 57-year-old, very poorly nourished white man, entered the Research and Educational Hospital Jan. 19, 1942, complaining of a painless, progressive jaundice of

Case 4 W D Carcinoma of common hepatic duct

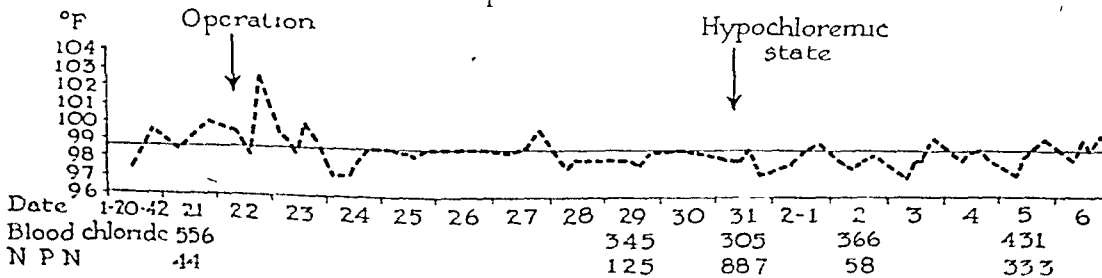


Fig. 4.—This patient had an external biliary fistula with extreme loss of chlorides due to the extensive loss of bile through the fistula. The postoperative course shows the gradual lowering of the temperature and also the gradual lowering of the blood chlorides which reached 305 mg. per cent (blood chlorides) during the hypochloremic state. The body temperature was subnormal at this point and gradually rose to approach normal after the blood chlorides were elevated. It is also noted that the nonprotein nitrogen returned to normal after the blood chlorides returned to normal.

five months' duration. Exploratory laparotomy revealed a carcinoma of the common bile duct. This was resected and an external biliary fistula established; no attempt was made to establish an internal biliary fistula at this time because of the patient's precarious condition. Due to the loss of at least 2,000 c.c. of bile daily, the patient relapsed into the hypochloremic state several times in spite of a relatively large intake of salt. The symptoms of crampy abdominal pain, subnormal temperature, cold clammy skin, nausea, and vomiting accompanied by hiccoughs were similar to the other cases reported. A jejunostomy was performed March 11, 1942, to facilitate the return of bile to the gastrointestinal tract. The patient expired on March 14, 1942. The autopsy findings disclosed a bronchopneumonia of the left lower lobe and multiple liver abscesses as the immediate cause of death.

COMMENT

I am in accord with Collier and his associates relative to the caution which should be used in the administration of salt in the surgical patient. This is especially important in the older age group of patients postoperatively, because any additional load, no matter how slight, may be too much for the presenile kidney. However, there are exceptions (particularly when there is abnormal loss) as Collier and his co-workers have stated, where salt therapy is allowed and needed postoperatively. The four clinical cases presented are dramatic exceptions to the "no salt rule postoperatively." In fact, it is extremely important that the hypochloremic state be recognized immediately for not only is salt indicated, but in large amounts and rapidly. This need for salt may total as much as 80 to 100 Gm. of sodium chloride in twenty-four hours for a patient whose blood chloride reading is less than 300 mg. per cent, particularly when the source of the chloride loss persists. Whether the electrolytes are to be given in physiologic saline, Ringer's, or Hartmann's solution will depend upon whether there is a compensatory alkalosis or a complicating uremic acidosis to be treated. It might appear that salt given in the amount discussed, to an older patient with impaired kidney function, postoperatively, would necessarily throw him into a fatal uremia and anuria. Such would, of course, be true if a severe hypochloremia was not present and the source of the loss persistent.

Although a relatively rare clinical entity, the hypochloremic state deserves enough publicity so that it will be readily and easily recognizable. It is equivalent to "heat exhaustion" passing into the subacute or chronic phase due to the persistence of the chloride loss. Spontaneous recognition is difficult due to its rarity and the bizarre clinical picture presented. The physician must be aware of the clinical entities which may allow the loss of sufficient chlorides to produce the hypochloremic state. The conditions most commonly allowing the loss of large quantities of electrolytes are gastroduodenal drainage, pyloric obstruction with vomiting, persistent external biliary fistulas, high intestinal fistulas, electrolytic loss from large granulating areas, persistent fever and excessive sweating from a long operation during the sultry weather or both. Emergency facilities for determining blood chloride levels at night or over week ends should be made available. One patient (Case 2) entered the hospital Saturday afternoon and died the following Monday afternoon shortly after a blood chloride reading of 273 mg. per cent was returned, but obviously too late to aid in treatment. The diagnosis of hypochloremia was not made clinically; we consider this error a serious and preventable one because of the severity of the symptoms.

The *clinical manifestations* of the hypochloremic state may be classified as either prodromal or advanced. The advanced symptoms of the hypochloremic state are acute and very similar to those of surgical shock and extreme prostration. They are usually characterized by a subnormal temperature of 97 to 98°

F., a systolic blood pressure of 80 or below, and a very soft easily compressible pulse which is almost unobtainable. The skin is cold and clammy, and excessive thirst accompanied by extreme weakness and prostration are likewise common. These acute advanced symptoms may be preceded for several days by the prodromal symptoms which consist of mild cramplike persistent abdominal pain, nausea, moderate abdominal distention, and the vomiting of small amounts of bile-stained fluid repeatedly. In addition the patient may appear languid, drowsy, and apathetic and not infrequently may develop an intractable hiccough. Anorexia is almost always present and bowel movements or flatus is singularly absent. Other fairly constant findings are an oliguria of 100 c.c. or less with the symptom complex of uremia. The oliguria and uremia are apparently on an extrarenal basis as they both rapidly return to normal when the blood chlorides are elevated. The similarity of the symptom complex of the hypochloremic state to the clinical picture presented by salt intoxication, the "acute abdomen," postoperative ileus, and intestinal obstruction due to nutritional edema make them extremely difficult to differentiate, except for the low blood chloride reading and the clinical states mentioned, which allow an uncompensated loss of chlorides.

The importance of early diagnosis of the hypochloremic state cannot be minimized. The low chloride level of the body fluids and tissues is rapidly fatal because of the uncompensated alkalosis and extrarenal azotemia produced with its accompanying state of severe shock. The extreme weakness, lowered metabolic rate, and shock lead inevitably to other complications such as intestinal ileus, aspiration and hypostatic pneumonia, and the onset of a vicious cycle. Therefore, prophylaxis by recognizing the possibility of its occurrence through chloride determinations in the suspected case is very essential. Active therapy should revolve around massive fluid and salt therapy, preferably intravenously. Experimentally, Soffer and associates⁴ have shown that the intravenous injection of salt is retained in the tissues much more readily when supplemented by cortical adrenal extract parenterally.

Shock due to the acute hypochloremic state will not respond to the usual therapy of blood, plasma, and nonspecific intravenous fluids. Immediate and specific active therapy consisting of massive doses of salt and fluids is indicated parenterally. This should be supplemented by adrenal cortical extract which materially aids the body tissues in retaining the sodium and chloride ion. From 6,000 to 10,000 c.c. of physiologic saline solution parenterally may be necessary within the next twenty-four hour period to prevent a fatality. The Coller "clinical rule" as mentioned previously in the text is an extremely accurate guide in salt replacement therapy. This allows the patient .5 Gm. of sodium chloride per kilogram of body weight for every 100 mg. per cent below 560 which is the lower limits of normal for the plasma chloride reading. Once the hypochloremic state has been corrected, a daily maintenance dose should be established by the "volume-for-volume" method as suggested by Coller, which is based on the amount of electrolyte still being lost. This can be supplemented by daily blood chloride determinations. The patient's clinical state and his physiologic response to appropriate test doses of salt are other valuable guides as mentioned previously. Obviously too much salt should not be given because salt intoxication and edema are almost as likely to lead to a fatality as hypochloremia. The miraculous clinical cures obtained by massive salt therapy are illustrated by Cases 1 and 3. The possibility of a rapidly fatal clinical course is illustrated by Case 2, in which the patient had a carcinoma of the pylorus with

remarkably little vomiting but a blood chloride reading of 273 mg. per cent. He died less than forty-eight hours after admission. The severity of his hypochloremia was not appreciated until just before death.

The interpretation of blood chloride readings is important as the normal values vary, depending on whether the whole blood or the plasma chloride reading is being used. The normal whole blood chloride values are 450 to 500 mg. per cent. The plasma chloride values are 580 to 650 mg. per cent. The lower value of the whole blood is due to the sodium chloride content of the red blood cells being much below that of plasma and serum. Therefore, knowledge of what type of chloride estimation is being performed and what the normal limits are for that particular estimation is essential. The salt content of bile is approximately the same as that of plasma or serum. However, it may be slightly higher as the liver has some power of concentration even after cholecystectomy. The chloride estimations used in this paper are for whole blood (normal 450 to 500 mg. per cent).

Obviously, one must be careful not to overload these patients with too much salt once they have been rescued from the acute lack of sodium chloride. Therefore, daily blood chloride determinations should be routine follow-up control as well as the physiologic response of the patient to test doses of appropriate salt solution. As is well known, salt edema alone or in combination with nutritional edema can produce complete intestinal obstruction at the anastomotic site postoperatively. The happy medium may be extremely difficult to obtain in patients unable to take anything orally, especially when losing electrolytes by the methods just mentioned.

SUMMARY

Four clinical cases of the *hypochloremic state* occurring in surgical patients are presented. The necessity for immediate recognition and differentiation from acute surgical conditions demanding operative intervention such as the "acute abdomen" or from salt intoxication and postoperative ileus which demand radically different nonoperative therapy is emphasized. In the hypochloremic state an abnormal loss of electrolytic fluid by gastroduodenal suction, pyloric obstruction, external or high intestinal fistulas, extensive granulating areas, and excessive loss of perspiration or allied causes is always demonstrable. The immediate postoperative period or warm sultry weather is the time period when this state is most likely to occur, especially when the abnormal loss of salt is prolonged. The loss of sodium chloride may become pernicious if not corrected, due to the accompanying dehydration, compensatory alkalosis, and further loss of chlorides by vomiting which is almost always present secondarily in the hypochloremic state. Immediate diagnosis is of vital importance because patients in the acute hypochloremic state are as ill as those with acute intestinal obstruction, and may die within a relatively short period of time unless massive salt therapy is instituted.

The various clinical features may be summed up as follows. The possibility of the hypochloremic state should always be kept in mind when considering surgical complications, especially postoperatively. It should be noted whether any abnormal loss of electrolytes has occurred and particularly whether or not such loss has been present for several days without being compensated for. If in doubt, an emergency blood chloride determination should be obtained. Any reading in the neighborhood of 300 mg. per cent or lower demands immediate consideration in therapy. The value of an emergency blood chloride determination is tragically demonstrated in the patient (Case 2) w

ing returned Monday noon with a value of 273 mg. per cent shortly after his death. He had entered the hospital Saturday afternoon, thirty-six hours previously, and had had an incorrect clinical diagnosis.

The clinical manifestations in the acute hypochloremic state may be exemplified in a patient suddenly found in shock with a cold clammy skin, subnormal body temperature, unobtainable or weak pulse, systolic blood pressure of 80 or below, with complete prostration and at least partial mental confusion. This acute shocklike state is found when the blood or plasma chloride reading drops to approximately 150 mg. per cent below the lower limits of normal. For several days previously this acute hypochloremia may have been preceded by nonspecific prodromal symptoms such as the vomiting of small amounts of bile, abdominal distention, mild crampy abdominal pain, hiccoughs, inability to pass gas, and extreme weakness. The latter clinical symptoms are usually noted when the blood or the plasma chloride readings are between 50 to 150 mg. per cent below the lower limits of normal. The output of urine, bile, gastroduodenal suction, or vomitus during this prodromal period has usually been tremendous and is always more than the fluid and electrolytic intake. This leads to acute dehydration, oliguria, compensatory alkalosis, and extrarenal azotemia with the onset of the acute hypochloremic state and its accompanying shock. The alkalosis or acidosis is disregarded as this disturbance of the acid-base balance, along with the elevated nonprotein nitrogen, automatically returns to normal with the correction of the hypochloremic state. Gamble⁵ has emphasized that sodium chloride given with an abundance of water will correct either alkalosis or inorganic acidosis, the kidneys excreting the unnecessary ion.

The specific therapy of acute hypochloremic prostration is massive salt and fluid replacement parenterally. Sodium chloride in amounts of 80 to 100 Gm. during the first twenty-four hours is occasionally necessary to bring the depleted patient out of the critical condition into which he has suddenly lapsed. A daily maintenance dose of 30 to 40 Gm. of salt may be necessary when the abnormal chloride loss is excessive and very difficult to control, as in Case 3. The Coller "clinical rule" for the replacement of sodium chloride is a valuable guide in the treatment of the acute hypochloremic state. As a general rule, no salt should be given to surgical patients during the first few postoperative days; however, occasional cases may arise where intensive salt therapy is definitely indicated.

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NEW TECHNIQUES FOR PARENTERAL FLUID AND DRUG ADMINISTRATION

I. MUSCULAR INTUBATION

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DEVELOPMENT of modern plastics and discovery that they are well tolerated by the tissues have opened important fields beside their installation as prosthetics. Investigators in the pharmacotherapy unit at Harvard (Drs. E. B. Astwood, J. F. Marchand, and B. Zimmerman) found that small tubes of vinyl chloride polymer were well tolerated in veins in the dog for many days of continuous infusion, and were less readily dislodged than cannulae. This suggested to them clinical application where cannulae, Lindemann needles, or even repeated venipunctures for infusions would ordinarily be used. I was invited to assist in development of the intravenous technique and its clinical testing. The highly gratifying results obtained and the methods developed will be described in subsequent publications. It is, of course, understood that venous intubation is in itself not new, but it is felt that use of the very fine and pliable but tough plastic tubes instead of the bulky, costly clot-promoting ureteral catheters or rubber tubes formerly used, is an important advance, particularly in eliminating the need for cutting down upon relatively small veins.

This communication is to call attention to a further development apparently not heretofore described—muscular intubation with plastic tubes, specially created for these purposes and flexible as ordinary twine.* It will be recalled that penicillin must be given parenterally (at least until proposed oral forms become applicable), and that because of its rapid destruction and excretion, intramuscular injection every three hours is standard practice. Use of an oily or poorly soluble menstruum has been proposed to reduce injection frequency, but raises further obvious questions as to variation in the effective concentration of drug and of untoward reaction from accumulated menstruum. In any case, the maddening repetition of the usual injections becomes a serious matter to the sick, weary, and nervous patient, interfering with sleep and sometimes growing to an obsession about needles.

Encouraged by success with venous intubation suggested by the Harvard group, it occurred to me that by inserting plastic tubes deeply into the muscle, injections could be given without disturbing the patient. It has been found clinically that one-half million units of penicillin may be given daily at the same site for one week with negligible reaction.

To facilitate injections an "ampule adaptor" was devised, to mount an ordinary small ampule cap on the external end of the tube. The nurse then merely tips up the cap, sterilizes it with iodine, and slowly injects into it the individual dose of penicillin. This may often be done without waking the patient. We have used sodium penicillin, made up in solution with physiologic saline so that the desired dose is contained in exactly 1 c.c. (or 1.2 c.c. in the case

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of a patient receiving 60,000 units in each dose). Patients to receive doses beyond this range of magnitude have been given a continuous clysis through the tube into the muscle, with for example 500,000 units dissolved in 240 c.c. of saline solution daily. This gives a high and constant titer in the body fluids with a surprising degree of freedom from local reaction. Patients who have received penicillin via plastic tubes, after experience with the usual method, are unanimous in keen appreciation of them. Instructions are given to move the involved muscles naturally, and if any local "full" feeling is noted after an injection, to rub the area gently to promote dispersal.

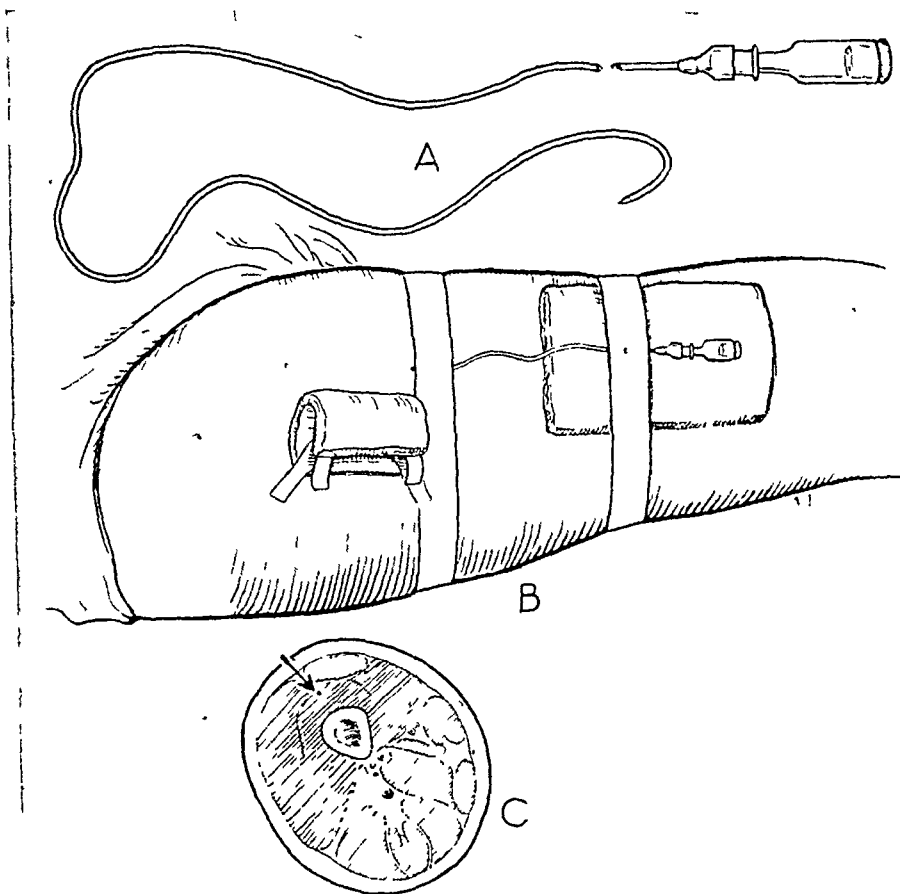


Fig. 1.—A, Enlarged view of tube and ampule adaptor. B, Side view of thigh, with covering compress removed and puncture dressing laid back, showing tubing as installed in outer side of right thigh. C, Cross section of thigh with tube lying deep in lateral musculature.

Nurses must be cautioned not to use this convenient little adaptor for injection of such substances as liver extract; the nonirritating nature of the tube naturally cannot alter the inadvisability of injecting certain medications repeatedly in one spot. Careful clinicians should find on further investigation that a number of medications ordinarily given by multiple injections are well tolerated when thus placed deeply into the muscle. Meanwhile this note is published in the hope of alleviating the real discomfort of the thousands receiving penicillin injections daily, some of whom refuse to continue medication of which they are in serious need. An application suggested by the originators of the plastic intubation, and by many who have seen it since, is in continuous spinal anesthesia. It offers obvious advantages, as it may be obtained finer

than the lead in a mechanical pencil, and despite its strength may be stretched over twice its length without breaking. Low cost permits discard after a single use. Spinal use will be discussed after suitable spinal techniques have been further studied. The tubing has also been placed through a tympanic perforation occurring in otitis media, for local penicillin therapy in the middle ear. Antral irrigation every three hours by indwelling plastic tubes has been similarly suggested. Details of the technique for muscular intubation follow.

The selected tubing passes readily through a 17 gauge needle. It is cut into twelve-inch lengths and sterilized by boiling for thirty minutes. The ampule adaptor consists of a Luer-tipped glass tube bearing a rubber ampule cap, and a dulled, short bevel, 22 gauge needle of one-half inch length. The glass tube can be made from the Luer tip supplied with most intravenous sets, cut and fire-glazed to give snug fit with a rubber cap. The entire adaptor is sterilized with an obturated 17 gauge spinal needle five and one-half inches long, which is used for introducing the tube into the muscle.* The stylet of the spinal needle prevents plugging of the needle mouth by fat particles during the insertion, so that the rather limp tubing may be readily pushed into the tissues as the needle is withdrawn.

The site is shaved if hairy, widely prepared with iodine and alcohol, and draped with three sterile towels. Sterile gloves should be worn. A dermal wheal of 1 per cent novocain is raised in mid thigh at juncture of anterior and lateral aspects. The spinal needle is thrust smartly cephalad and slightly medially, deep into the vastus medialis muscle. It may be pushed up with the skin to gain as much depth as possible. The obturator is then withdrawn and the tubing (with end cut off squarely) is threaded into the needle. While the tubing is being pushed on, the needle is withdrawn; the tubing may be fed directly into the needle hub with thumb forceps to minimize tendency to buckling. After the needle has been withdrawn one-third of its length, the tubing may be released and observed. It should be dragged into the hub as the needle is further withdrawn, showing that the tissues have seized the tube tip. Pressure may then be applied on the overlying skin to aid in retaining the tubing as the needle is cautiously stripped back out of the thigh and off the tube. If the tubing should for any reason fail to lodge at full depth in the muscle (an India ink marker placed five inches from the tip before sterilizing is helpful), it should be entirely withdrawn and re-inserted—subcutaneous deposition of solution is a cause of discomfort, poor absorption, and pocket formation. The plastic tubing is taped directly to the skin by a piece of one-inch adhesive eight inches long, just below the point of emergence of the tube. It is desirable to be able to observe the entry site but the tubing should be taped closely so that it cannot work in and out of the skin as the limb is moved. A sterile compress is then centered over the minute entry puncture by tape diagonally securing its corners. The adaptor is inserted into the free end of the tubing and taped loosely to the skin at a convenient point. A folded compress is placed under the adaptor unit so that it will not press directly on skin. A short piece of tape with adherent side upward may be placed under the adaptor tape at this point, holding the adaptor securely but allowing it to be tipped up for injection, and facilitating renewal of the compress beneath if it becomes soiled with iodine in preparing the cap for injection. Finally, a large compress is taped over the installation as a whole to keep clothing from catching on it. If one corner of this compress is placed over the adaptor it provides a tab which may be turned back to expose it for each injection without disturbing the dressing.

*Prepared for this work by courtesy of Becton, Dickinson & Co.

After use for several days the tube should be withdrawn and a different site intubated. (The tubing is discarded rather than cleaned, a boon to the nursing staff.) Alternating injections between simultaneously placed tubes is illogical, for then neither region used is truly rested from the solution, and it has been found that use of single areas with periodic relocation gives excellent results even with unusually large doses. Reinstallation every four days saves the patient thirty-one out of the thirty-two punctures otherwise required, and the remaining puncture (for the intubation) is made at the doctor's convenience with novocain. Patients may be ambulatory while undergoing discontinuous injections, and may move far more freely during a clysis technique than if stiff needles were used.

Grateful acknowledgments are due Miss Balbina Johnson of Surgical Bacteriology for sterility tests and for valuable suggestions; to the Departments of Medicine and Otolaryngology for clinical trials (Dr. T. Hunter and Dr. R. Robertson), and to the staff of the Babies Hospital.

STUDIES ON THE MECHANISM OF CITRATE INTOXICATION IN MASSIVE TRANSFUSIONS OF WHOLE BLOOD

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THE recent widespread practice of administering large amounts of citrated whole blood and plasma in the prevention and treatment of shock represents a major advance in the surgical care of patients. Investigative work in this field has resulted in a warning issued against the too liberal use of citrated blood. Ivy and his co-workers¹ found that animals bled 45 to 65 per cent of their estimated blood volume died in 84 per cent of cases if no replacement was made. If citrated whole blood or plasma was given over a five-minute period to replace the loss, 50 and 70 per cent, respectively, of the dogs died. If heparinized plasma were used for replacement, only 6 per cent of the animals died. Ivy and his associates concluded that 1,500 to 2,500 c.c. of citrated whole blood or plasma given rapidly to a man weighing 70 kilograms might prove fatally toxic. Bruneau and Graham² reported experiments in which dogs were bled 10 per cent of the estimated blood volume and the blood then reinjected during a one-half hour period. The reinjected blood contained either 0.6 per cent sodium citrate or heparin; the hemorrhage and replacement were repeated until the animals died. The dogs receiving the citrated blood expired after an average of 9.25 hemorrhages, or approximately 92.5 per cent of the estimated blood volume, while the dogs receiving heparinized blood averaged 25.2 hemorrhages, or 252 per cent of the estimated blood volume before death occurred. It was obvious from these experiments that some other factor than sodium citrate contributed to the death of the animals, but citrated blood was much more deleterious than heparinized blood.

First we undertook experiments³ similar to those reported by Ivy and associates.¹ We found, as he did, that citrated blood given rapidly to treat

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shock produced by hemorrhage resulted in the death of the animal. However, dogs could be bled as much as 60 per cent of the estimated blood volume, and survive, if the replacement by citrated whole blood was made over a period of twenty minutes or longer. Evidently the sodium citrate was detoxified and excreted fairly rapidly: When bleeding and transfusions were conducted simultaneously an average of 122 per cent of the estimated blood volume was exchanged during a period of seventy minutes before the animal expired. When the rate of bleeding and transfusion was less rapid, a larger volume was exchanged without reaction. We concluded that the time of administration determined whether a serious or fatal reaction would occur, and felt that transfusions were rarely, if ever, given at a rate likely to cause citrate reactions in man. Calcium gluconate was found to be very effective in preventing or alleviating citrate intoxication when very large doses of citrate had been administered during a short period of time.

METHODS AND RESULTS

In the present study we attempted to perform experiments somewhat similar to those reported by Bruneau and Graham.² We felt that it should be possible to bleed and transfuse a dog indefinitely, providing the blood loss was replaced simultaneously. We modified our experiments to this extent: instead of bleeding the animal a given amount, and then replacing the loss, we obtained 200 c.c. of whole blood from another dog to use as a reserve supply. This blood was infused into a femoral vein as we conducted bleeding from the opposite femoral artery. The blood removed from the femoral artery was added to the blood in the flask leading to the vein. At the conclusion of the experiment 200 c.c. of whole blood remained in the flask to the femoral vein. In this way we could bleed and transfuse dogs simultaneously; at any given moment the status of the circulating blood was theoretically the same as when the experiment began, since bleeding and replacement were approximated.

Three experiments were performed with heparin. The animal was anesthetized with ether, one femoral vein cannulated for infusion, and the opposite femoral artery cannulated for bleeding. For convenience, 100 c.c. units were withdrawn. Each 100 c.c. of blood was heparinized by withdrawing it into a flask containing 0.1 c.c. heparin* in 5 c.c. of saline solution. As the first 100 c.c. were withdrawn, 100 c.c. of heparinized blood from a donor was injected. For the remainder of the experiment, the animal's blood was merely heparinized and reinjected. Dog 63 weighed 8.8 kilograms. The estimated blood volume was 880 c.c. He was bled 8,800 c.c. and transfused this amount of heparinized whole blood in five and one-half hours. He was sacrificed in eight days. No ill effects were noted. Dog 66 weighed 9.2 kilograms and had an estimated blood volume of 920 c.c. He was bled and transfused 9,200 c.c. in one hour and fifty-one minutes. No ill effects were noted and he was used in a different series of experiments two weeks later. Dog 15 weighed 14.3 kilograms and had an estimated blood volume of 1,430 c.c. He was bled 14,300 c.c. and transfused with this amount of heparinized whole blood in fifty-seven minutes. No ill effects were noted during a period of observation of two weeks.

Three similar experiments were run with citrated blood. The bleeding and transfusion were conducted as in the heparin studies. Each 100 c.c. of blood was drawn into a flask containing 20 c.c. of sodium citrate† and 3 c.c. of calcium gluconate.‡ It was necessary to agitate the blood constantly to

*Lederle, 1 c.c. = 10 mg. heparin.

†U. S. Standard Products Company, 2½ per cent solution sodium citrate.

‡Sandoz, 20 per cent calcium gluconate.

prevent clotting after the calcium gluconate was added. The experiments could not have been attempted without the addition of calcium gluconate since the animals would have soon died of citrate intoxication. Dog 105 weighed 7.3 kilograms and had an estimated blood volume of 730 c.c. Over a two-hour period he was bled 7,300 c.c. and this was replaced simultaneously with citrated, gluconated whole blood. The animal died two hours after the experiment was finished. Dog 114 weighed 8.3 kilograms and had an estimated blood volume of 830 c.c. He was bled and transfused 8,300 c.c. and died one hour after the study was completed. Dog 158 weighed 6.0 kilograms and had an estimated blood volume of 600 c.c. He was bled and transfused 6,000 c.c. in sixty minutes. This animal died shortly after the infusion was complete. Autopsies on these dogs showed generalized edema. Dogs 105 and 158 had marked pulmonary edema and Dog 114 had about one liter of free fluid in the abdomen. The kidneys were not abnormal. If one takes into account the volume of the sodium citrate and calcium gluconate added to the blood in these animals they received 230 c.c. of fluid per kilogram added to the circulating blood. This was thought to have been the principal cause of death.

Therefore, three animals were anesthetized and infused with 230 c.c. of physiologic saline solution per kilogram. No bleeding was done. Dogs 694, 695, and 690 weighed 12.5, 9.5, and 13.6 kilograms, respectively, and received 2,875, 2,185 and 3,128 c.c. of saline, respectively, in sixty minutes. All the animals showed marked enlargement of the abdomen and two (Dogs 694 and 690) had large, watery evacuations of the bowel at the end of the experiment. The respirations became hindered by fluid in the lungs. One animal (Dog 694) died within twenty-four hours and showed ascites (1,000 c.c.) and extensive edema of the lungs. Dog 695 was sacrificed in twenty-four hours and had edema of the tissues, but no marked ascites or pulmonary edema. The kidneys were very pale and swollen. Dog 690 recovered and was not sacrificed.

DISCUSSION

The experiments with heparin demonstrate that a dog can tolerate a remarkable turnover of the blood. To accomplish this certain hazards such as the production of shock must be avoided. The animal will not tolerate indefinitely repeated small lowerings of blood pressure. This is demonstrated by the experiments of Bruneau and Graham.² Our work is subject to the criticism that the dog's blood was reinjected. We feel that blood from other animals would have been just as satisfactory, but it is no small problem to obtain the volumes of blood used in these studies. The experiments using citrated blood conclusively prove that some disturbing factor was at work. Ivy and Bruneau and their co-workers had demonstrated this previously. However, since calcium gluconate had been used in these animals to restore calcium ions, we felt that some other factor was at fault. It occurred to us that the dogs who had their blood volume depleted and replaced ten times with citrated blood received, in addition, 230 c.c. of fluid per kilogram during the course of the experiment. It seemed that this might be responsible for the edema and death of the animals. For that reason 230 c.c. of physiologic saline solution per kilogram were given to three animals. It is not surprising that only one dog died, since physiologic saline solution produces less alteration of the state of the blood than any other solution commonly used. Warthen⁴ demonstrated this and found that 65 to 175 c.c. of 0.7 per cent NaCl per kilogram of body weight injected into dogs in thirty minutes caused no reaction. It seems likely, then, that death in the animals receiving citrated blood

protected with calcium gluconate was due to overloading the blood stream with resultant pulmonary edema.

One more study should be made. The blood of dogs undergoing the experiments just cited should be perfused through a frog's heart preparation to test the toxicity of citrated blood with and without calcium gluconate protection. These experiments were planned, but abandoned because of shortage of personnel.

SUMMARY AND CONCLUSIONS

1. If shock is avoided a dog's blood volume may be depleted by bleeding and replaced by transfusion as many as ten times, using heparinized blood, without ill effects.

2. Dogs usually die if the same procedure is carried out using citrated blood, even though calcium gluconate is added.

3. This is thought to be due to the overloading of the blood stream by the large volume of fluid used to convey the sodium citrate.

4. It seems unlikely that any of the reactions seen in laboratory experiments would occur in man, and one should not hesitate to give massive transfusions when indicated.

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A MODIFICATION OF THE GIUS-RACELY PORTABLE SUCTION APPARATUS

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GENERAL

AT THIS station a variety of suction devices have been used to decompress the intestinal tract in patients with abdominal distention due to intestinal obstruction, of the mechanical or paralytic types. Two-bottle and three-bottle sets have been employed to remove gas and fluid from intubated patients, but these methods have been clumsy, inefficient, and troublesome to all concerned, including the patient. We sought a more efficient and practical mechanism, and were pleased to find an article by Gius and Racely,* describing a new portable suction apparatus in which suction is produced through their two-bottle system by using a single cylinder tire pump.

With their idea in mind, we set out to build a similar device, but substituting a smaller pump. A shuttle pump was employed to initiate suction

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*Gius, John A., and Racely, Clay A.: A New Portable Suction Apparatus for Use With the Miller-Abbott Tube, *SURGERY* 15: 574, 1944.

and this proved to be easy to operate and remarkably efficient. We found this new device to be very satisfactory and it has been enthusiastically received by the medical and nursing staffs concerned.

DESCRIPTION OF THE APPARATUS AND ITS CONSTRUCTION

Two one-gallon bottles are inclosed in a light wooden box. On one side of the box, a "shuttle" pump is mounted with the handle on the outside and it is operated with an easy motion. The handle can be rocked to-and-fro with gentle

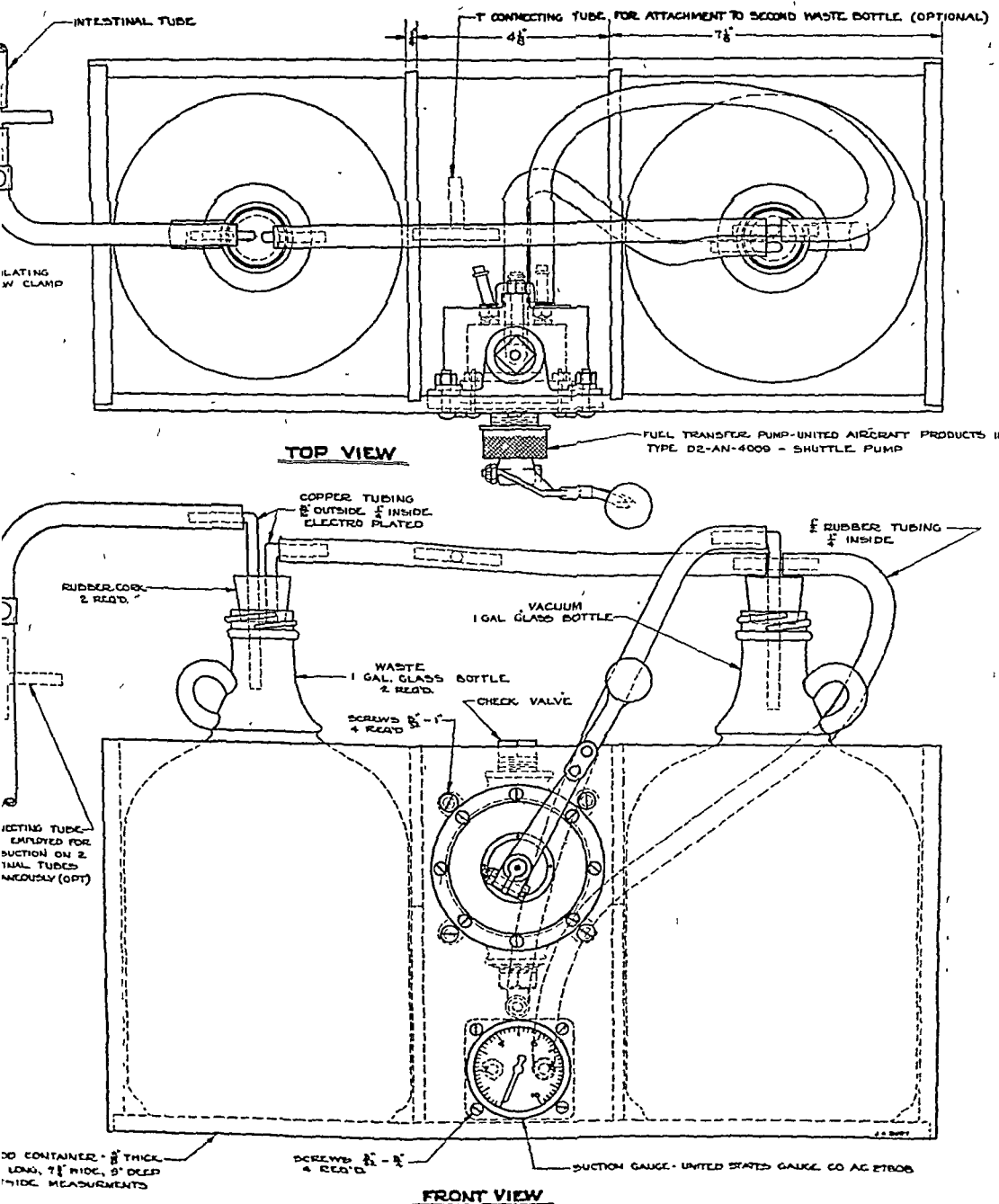


Fig. 1.—Photograph of detailed drawing of portable suction apparatus showing front and top views. Note optional insertions of T tubes included to suggest possible use for decompression of two or more patients simultaneously. (Official Photograph by U. S. Army Air Corp.)

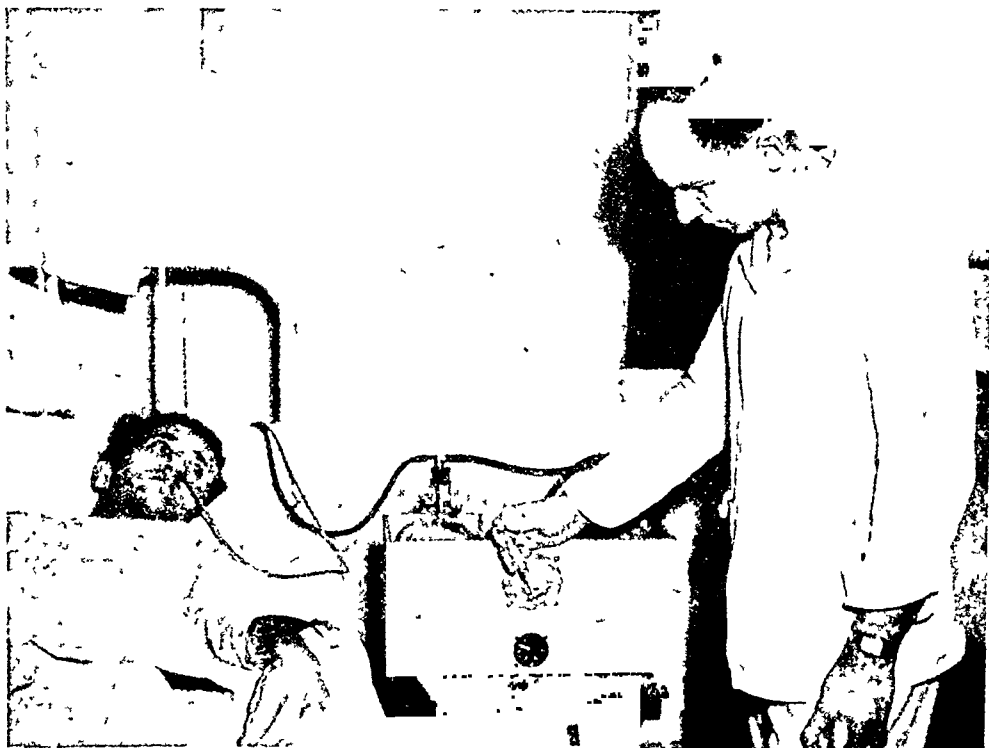


Fig. 2.—Apparatus in use on a patient with a paralytic ileus. Miller-Abbott tube is being used for intubation (Official photograph by U. S. Army Air Corp.)



Fig. 3.—Same case as Fig. 2; the patient is demonstrating the ease with which the shuttle pump may be operated by all but the acutely ill. (Official photograph by U. S. Army Air Corp.)

pressure between the thumb and index finger of either hand. The two bottles are connected with each other by rubber tubing through two two-hole rubber stoppers with tube connectors. In our set, three right angle and one T-tube connectors are used. The intestinal tube is connected to the waste bottle, the pump being connected to the vacuum bottle by means of similar tubing and connections. A manometer giving the negative pressure reading within the system is connected to the vacuum bottle. Operation of the pump removes the air from the system and suction is produced on the intestinal tube through its attachment to the waste bottle. This bottle acts as a reservoir for the gaseous and fluid contents to be removed. (See Figs. 1 to 4.)



Fig. 1.—Photograph made inside a hospital airplane showing proposed use in air evacuation of the wounded. (Official photograph by U. S. Army Air Corp.)

OPERATION OF THE APPARATUS

The suction device may be placed beside the patient's bed, on a table or a chair. Preferably it should be one to two feet lower than the body, to develop a siphon effect, but it can be operated at the same level as the patient without the aid of gravity. Before operating the shuttle pump to create suction in the system, the intestinal tube should be clamped off to eliminate any possible damage to the gastrointestinal mucosa by sudden change in pressure in the openings in the end of the tube. We have found that an effective negative pressure range with this machine is two to four inches of mercury (50.8 to 101.6 mm.). Less suction is required to produce evacuation of gastrointestinal contents through a single lumen tube, such as the Levin tube, than through the use of the double-lumen Miller-Abbott tube, the latter being longer and of smaller diameter. Two to three inches (mercury) of negative pressure (50.8 to 76.2 mm.) are adequate for the single-lumen tube and three to four inches (76.2 to 101.6 mm.) are satisfactory for the double lumen tube. Once the desired amount of negative pressure has been created in the bottles, as

on the gauge, the intestinal tube can be opened and the rate of drainage regulated as desired, by means of a screw clamp. We have found that when the negative pressure has been lowered to four inches (101.6 mm.) of mercury, 950 c.c. of fluid, or an equivalent amount of gas, will be evacuated, when the base of the suction device is level with the tip of the suction tube. With the base of the device twenty inches below the level of the tube tip, a siphon effect is obtained and 1,300 c.c. of fluid will be delivered into the waste bottle.

The first device that we constructed had no provision for preventing back leakage of air through the pump, with a fairly rapid loss of negative pressure and consequent loss of suction. This was prevented by clamping off the tube from the pump to the vacuum bottle after operation of the pump. Its operation was somewhat complicated, but this disadvantage was minimized on a subsequent model by placing a check valve on the outlet valve of the pump. Thus, back leakage into the bottles was prevented when the apparatus was in use.

SUMMARY

A suction device for gastrointestinal decompression has been described. It is an efficient, easily operated mechanism, which may be transported with the ease of a small handbag from ward to ward, in the hospital. It weighs 12¾ pounds. The parts required for construction should be available at any Army Air Force installation. It is primarily for use in cases of gastric and/or intestinal distention due to paralytic ileus or intestinal obstruction of the mechanical type. It also has been used effectively for pharyngeal suction after applying an appropriate suction tip. We feel that it would be ideal for use in air evacuation on patients requiring continuous suction, due to the fact that it is so compact and efficient. This apparatus may be used to decompress several patients simultaneously by inserting T-tube connectors at the appropriate sites (see Fig. 1).

The device described is a modification of the suction apparatus described by Gius and Racely, and we acknowledge the stimulation which it provided in the construction of our machine. We feel that the pressure gauge and the shuttle pump are a decided improvement and though they add expense in construction, promote efficiency in operation.

The authors wish to express appreciation to Major J. M. Lynch, M.A.C., who arranged for the construction of the apparatus and to Harry E. Hill and Joseph P. Quinn who built the machine. Drawings of the apparatus were made by Joseph A. Burt. Photographs were made by Lieutenant Cala G. Harrison, Base Photographic Officer.

SPICULAR FOREIGN BODIES IN ESOPHAGUS

REPORT OF THREE UNUSUAL CASES

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ELONGATED pointed foreign bodies, such as pins, needles, and bones, especially fish bones, are frequently encountered at the base of the tongue, in the tonsillar regions, and in the hypopharynx but seldom in the esophagus. When meat, however, is attached to a fragment of bone, it often lodges in the esophagus. Unless a foreign body which is thought to be spicular in shape can be visualized when the entire pharynx is examined, the opinion may be expressed that the object has passed into the stomach and that the residual symptoms are emotional in origin.

The exact location of a metallic foreign body can be determined by roentgenoscopic examination, but errors may occur in that a patient may think he has ingested a metallic foreign body when actually he has swallowed something that is nonopaque to roentgen rays. Fragments of bone that lodge in the esophagus are usually found just below the cricopharyngeal constrictor muscle and may be identified in a lateral roentgenogram. Bones are not demonstrable when roentgenograms are made with the patient in an anteroposterior position. Calcification of laryngeal cartilages or of other structures in the cervical region may be mistaken for intraesophageal foreign bodies and frequently foreign bodies may be overlooked on roentgenoscopic examination.

In the majority of cases of suspected foreign body in the esophagus, direct inspection should be made through an esophagoscope, for this is the most accurate and the safest method of diagnosis and treatment. Passing stomach tubes into the esophagus or advising a patient to eat corn bread or bread crusts in an effort to dislodge a foreign body are procedures that date back to an era less enlightened than our present day. Of course, there are neurotic persons who have many sensations that persist in the throat for months or years. These patients should be treated kindly and sympathetically but usually should not be examined with an esophagoscope. However, when symptoms suggesting a foreign body have been present for less than one week, esophagoscopic investigation is usually indicated.

When the presence of any type of foreign body is suspected in the esophagus, a mixture containing barium should not be ingested to facilitate roentgenoscopic study. Iodized oil is preferable for this purpose, since it will not obscure a foreign body nor will it interfere with immediate esophagoscopic examination.

CASE REPORTS

CASE 1.—An edentulous man, 50 years of age, was examined Nov. 20, 1942. Six years previously, while eating chicken, he thought he swallowed a bone. Symptoms persisted and two days later a physician passed a stomach tube, with apparent dislodgment of the foreign body. Six hours after passage of the tube, pain developed in the left side of the thorax and there was moderate elevation in temperature. Although the patient was not confined to bed, he felt bad for at least one month.

Recovery was then apparently complete for eighteen months, when fever again developed and he coughed up a moderate amount of blood and foul-tasting pus. Following this episode he had continuous cough, which was usually nonproductive save for once or twice a

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month, when he expectorated a small amount of pus and blood for one or two days. Prior to evacuation of this secretion, he had mild elevation in temperature. Administration of sulfonamide drugs seemed to hasten recovery from these exacerbations.

For one year or more previous to our examination, the patient had noted painful swollen joints, and this symptom was intensified during the periods of fever. When the accumulated secretion in the bronchi drained, he felt better in every way. Repeated roentgenoscopic and physical examinations of the thorax had not revealed a significant lesion (Fig. 1). The first bronchoscopic study of the patient disclosed nothing abnormal.

During the next two years the patient was examined repeatedly, and on six occasions bronchoscopic investigation was performed. At five of these examinations a small amount of

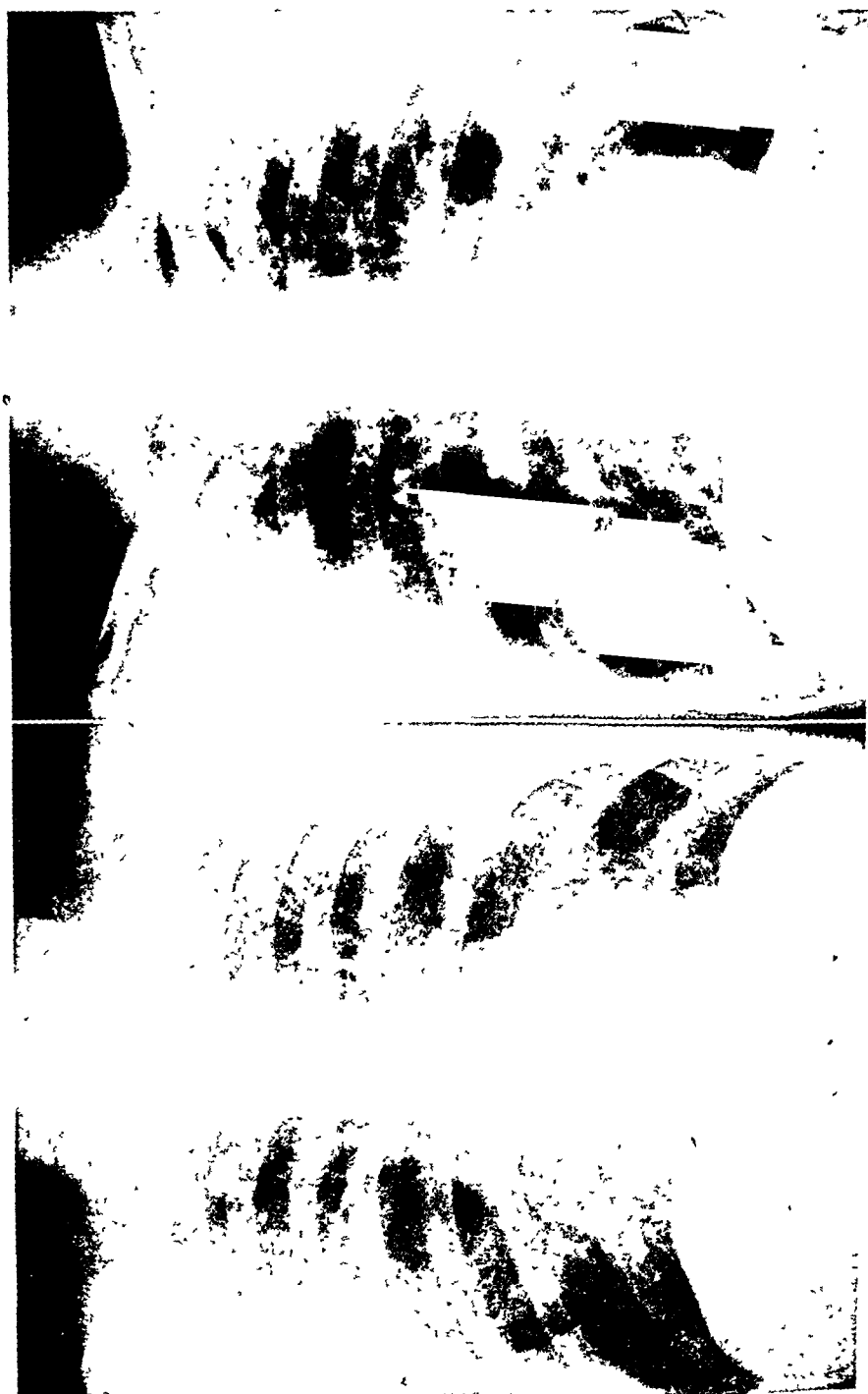


Fig. 1 (Case 1). Normal thorax.

Fig. 2 (Case 1).—Area of infiltration at periphery of left lung, with small cavity partly filled with fluid.

pus was found in the left main bronchus, and twice a tiny bit of blood was encountered, but no definite lesion was seen.

Sept. 21, 1944, when the patient returned for further study, he had had a more prolonged period of fever than usual, with expectoration of a larger amount of pus and blood than previously. A roentgenogram made at this time revealed an area of infiltration at the periphery of the left lung, with a small cavity partly filled with fluid (Fig. 2).



Fig. 3 (Case 1).—Iodized oil showing filling of cavity.

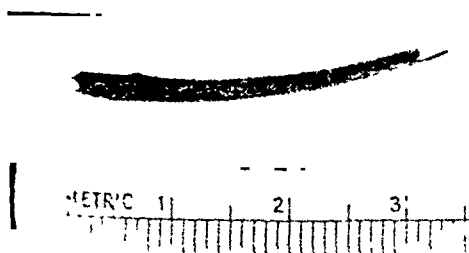


Fig. 4 (Case 1).—Spicule of bone removed surgically from left lung.

Broncho-scopic study then revealed pus and blood coming from the inferior division of the bronchus to the upper lobe of the left lung. Iodized oil was injected into this bronchial division, and a roentgenogram showed filling of the cavity (Fig. 3). Surgical drainage of the cavity was recommended, and at the time of operation a spicule of bone was found within the cavity and was removed (Fig. 4). The patient recovered completely and has remained well.

CASE 2.—A woman, 67 years of age, was admitted to Riverside Hospital, Newport News, Va., Sept. 7, 1944. Her chief complaint was severe lower substernal pain that had begun five days previously while she was eating an ordinary meal. The onset of pain was not associated with the sensation that a foreign body had been swallowed. The pain persisted and was

followed by elevation in temperature to 102° F. Just prior to being admitted to the hospital, she vomited a large blood clot.

Occlusion of one of the coronary arteries was suspected, but an electrocardiogram showed normal tracings. General physical examination revealed nothing significant pathologically, save that many teeth were absent and that the twelve that remained were loose and infected. Various laboratory studies showed normal findings, with a leucocyte count of 12,000. Twenty-four hours after admission, the patient suddenly died.

Post-mortem examination revealed a straight fish bone one inch in length which had perforated the wall of the upper portion of the esophagus and had entered the aorta, with fatal hemorrhage into the gastrointestinal tract (Fig. 5). On questioning her relatives after the bone was found, it was ascertained that at the onset of her illness the patient was not eating food that contained bones and that she had not eaten fish within one week of the beginning of her difficulty.



Fig. 5 (Case 2).—Fish bone, one inch in length, found at autopsy to have perforated the esophagus and aorta.

CASE 3.—A woman, 35 years of age, was examined March 7, 1945. She said that she had been well until December, 1943, when she had begun to lose a little weight. She had not consulted a physician until May, 1944, when nothing was found on physical examination to explain the loss of weight and she was merely advised to give up her work and take a prolonged vacation. She stopped working June 30, 1944. Three days later, July 3, 1944, while eating a piece of chicken, a pain suddenly developed in the right side of her throat. She was unable to swallow saliva without intensification of the discomfort and she had pain in the right shoulder and fever. These symptoms gradually subsided, and after ten days she was able to swallow solid food without a feeling of obstruction but with continued associated pain.

One month later she had a coughing spell, with evacuation of a moderate amount of foul-smelling bad-tasting pus and blood. These episodes of drainage occurred several times, and after each evacuation of pus and blood, she remained free of symptoms for several weeks. She had irregular elevation of temperature, depending on the adequacy or inadequacy of drainage from the lung. Roentgenograms revealed an area of density in the apical area of the right lung. Treatment consisted of administration of penicillin for two weeks during the latter part of August and the first part of September, 1944.

The patient's normal weight of 138 pounds had dropped to 110 during the acute illness, but at the time of our examination it was 143 pounds. The only significant findings at the time of our general physical examination of the patient were a partial upper dental plate and evidence of an impaired percussion note at the apex of the right lung anteriorly. Further

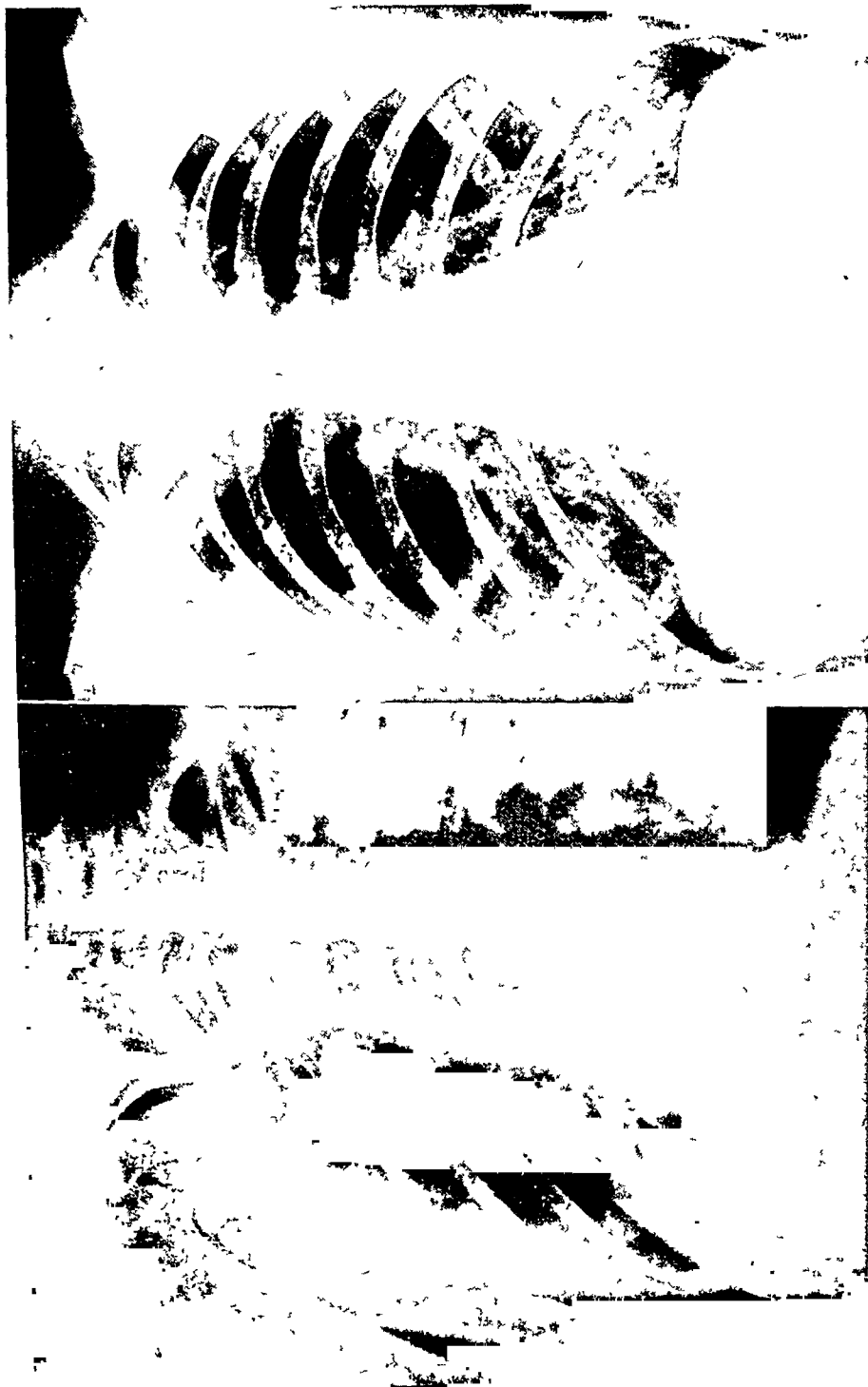


Fig. 6 (Case 3).—Defect on right wall of upper esophagus, representing probable exit of bone.
 Fig. 7 (Case 3).—Elongated shadow, apparently a bone, in right lung.

roentgenoscopic studies revealed a defect on the right wall of the upper portion of the esophagus, which probably represented the exit of the bone from the esophagus (Fig. 6). In line with this defect, presumably in the tissue of the right lung, was an elongated shadow, which was apparently a bone (Fig. 7).

The previously mentioned area was explored surgically without recovering the bone, but a small cavity communicating with a bronchus was encountered and drained. If symptoms recur, an effort will be made to remove the foreign body with a bronchoscope. At this writing, the patient looks and feels well and the thoracotomy is healing satisfactorily.

THE SURGICAL PROBLEM OF CANCER IN LYMPH NODES

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OF THE two routes of wide cancer dissemination, lymphatic and hematogenous, the lymphatic is clinically the more important. Cancer cells, because of their invasive tendency, break into capillary lymphatic channels and may grow along them for varying distances. Such lymphatic permeation probably takes place to some extent in all tumors which metastasize by way of these vessels. Retrograde extension from a secondary focus, such as a lymph node, may take place in like manner.

Junction of forward permeating cells from a primary tumor and of backward extending cells from an involved node area may occasionally take place in cases of marked advancement. Initial node involvement by progressive permeation from a primary site of disease to a normally distant node group must be a very rare incident. The only possible means of surgically coping with such situations is by uninterrupted excision in continuity of both the primary tumor and its draining node area. The prognosis in cases really requiring such extensive procedures will be extremely poor.

The more usual means of spread, however, once lymphatic invasion about a primary tumor has occurred, is by a breaking-off process of fragments of the tumor which then become lymphatic emboli. How long an interval is required for such emboli to travel from primary lesion to node is a matter for conjecture. Considerable variation probably exists. If India ink (particulate carbon) is introduced within lymphatics it may be found in the nodes seconds later.¹⁴ On the other hand, melanotic nodules may subsequently make their appearance in the lymphatics of an extremity in which two weeks or more have been permitted to elapse between primary excision and node dissection (Fig. 1). The size of the particle, cell, or cell cluster, as well as the velocity of the lymph stream, very likely has considerable influence on the speed with which the lymphatics are traversed and these clusters, if large enough, may therefore become arrested along their course. The afferent lymphatics enter the cortical sinus of a node where microscopic tumor emboli then first appear.

The old hypothesis that the hyperplastic changes in lymph nodes draining an area in which a tumor resides represent a reaction against metastases similar to that presented against bacterial toxins finds no substantiation. Lymph nodes appear to offer fertile soil to metastatic tumor growth and, when involved, render the prognosis distinctly worse than when involvement is not present. On the other hand, the nodes do act as interrupters in the dissemination process and it can be conceded that without them lymphatic invasion would add but another brief step to hematogenous spread.

This function of the regional lymph nodes is now generally recognized. Clinical demonstration of node involvement, it is unanimously agreed, should be dealt with by en bloc removal of the node groups apart from certain contraindications to be considered later. Considerable controversy exists regarding the

proper method of dealing with draining node areas in which there is no clinically demonstrable metastatic disease. Some prefer to adopt a policy of watchful waiting, relying on careful follow-up to dictate subsequent procedure, carrying out node dissection only if or when disease appears in these structures. Proponents of this policy argue that needless dissections are thereby avoided, the chief importance of which lies in the fact that these operations carry a varying but definite operative mortality. Opposed to this group are others who contend that prophylactic dissection should be carried out whenever one is dealing with a tumor of known metastasizing potentialities, although there is little agreement among them as to what extremes such action should be carried. It might be well to digress at this point in order to establish definitions.



Fig. 1.—Primary melanoma of skin of dorsum of foot, excised elsewhere three years previously. Two years later nodules were noted along the leg and thigh (circled). These were recently treated by combined excision of a wide strip of skin between the primary site and inguinal region and radical groin dissection.

Therapeutic dissection is generally intended to convey the idea that the size and character of the nodes have led to a preoperative supposition of clinical involvement. Prophylactic dissection implies that the nodes are suspected of containing disease despite the absence of physical signs indicating involvement. Since the distinguishing signs are entirely clinical, it is apparent that in both instances errors in diagnosis will occur which in percentage figures will vary not only with the type of tumor under consideration, but also with the skill and experience of the examiner. It is hardly possible to evaluate such a factor but its presence should be remembered. The proponents of prophylactic dissections argue that careful follow-up is subject to many uncertainties and quite cor-

rectly insist that the treatment of cancer in lymph nodes, as elsewhere, offers the best results when carried out as early as possible.

It is the purpose of this paper to examine the problem of node treatment from its several aspects in an attempt to determine how such treatment may be developed to maximum advantage.

NODE INCIDENCE: FACTORS RELATING CHIEFLY TO THE PRIMARY TUMOR

There is a well-recognized and wide variation in the frequency with which different tumors metastasize to lymph nodes (Table I). These variations are

TABLE I. NODE INCIDENCE IN SOME OF THE COMMONER TUMORS

TUMOR	PER CENT
Carcinoma, intrinsic larynx ¹⁶	10
Carcinoma, skin ¹⁸	12 to 15
Carcinoma, penis ¹⁸	25
Carcinoma, lip ¹³	31
Carcinoma, lower gingiva ³	35
Carcinoma, buccal mucosa ³	40
Carcinoma, vulva ¹⁹	46
Carcinoma, tongue and floor of mouth ^{9, 12}	63
Melanoma, skin ⁴	61
Carcinoma, rectum ^{*8}	68
Carcinoma, colon ^{*1}	70
Carcinoma, extrinsic larynx ¹⁶	70
Carcinoma, stomach ^{*2}	75
Carcinoma, breast ^{*17}	75
Carcinoma, tonsil ¹¹	77
Carcinoma, nasopharynx ¹⁰	80

*Only cases in which operation was done.

dependent on a number of factors which are partly anatomic and partly inherent in the primary tumor. Different sites of primary involvement appear to present varying degrees of resistance to local spread, and quantitative differences in the lymphatic system of the part alter the accessibility of invading cells to the node channels. Carcinomas of the intrinsic and extrinsic larynx often exemplify this quite well. Extension of a primary tumor from its original site to involve adjacent structures having their own lymphatic network will also exert definite influence. Morphologic differences of tumors of the same part are well-known factors, that is to say, whether the tumor is of adenoid or epidermal origin. This is particularly true of the carcinomas of the hard palate. Within these separate groups there also reside differences concerned with the degree of anaplasia of the tumor. Many of the reasons for the peculiarly varied manifestations of these groups and subgroups are not well understood and must await further enlightenment, but the differences are nonetheless present. In certain groups of tumors, activity inherent in grading follows rather consistently. Epidermal tumors are good examples. In others inconsistencies occur so commonly as to render any rule unworkable (notably adenocarcinomas of the breast). Other factors include the size of the lesion, whether the tumor is primary or recurrent, the nature of previous treatment, and the duration of symptoms.

Another consideration not discussed in the literature but which seems to be pertinent to the present problem relates to quantitative node involvement in dissection specimens from the various tumors and the relative frequency with which widespread metastases occur (Table II). It should certainly seem reasonable that if a tumor of a given description metastasizes with considerable regularity to only one or two nodes, remains confined there after all clinical doubt as to its presence has been dispelled, and very rarely kills by reason of more widespread dissemination, then such a tumor might as well be treated by

TABLE II. THE EXTENT OF NODE INVOLVEMENT IN POSITIVE DISSECTION SPECIMENS

SITE OF PRIMARY INVOLVEMENT	NUMBER OF CASES	AVERAGE NUMBER NODES INVOLVED	PER CENT WITH MORE THAN ONE INVOLVED NODE
Epidermoid carcinoma of skin	19	1.9	35
Carcinoma, penis, vulva, anus; bilateral dissections	6	1.8 (?)	50 (?)
Oral cavity (tongue, floor of mouth, buccal mucosa)	15	2.3	47
Carcinoma of lip	34	2.7	53
Melanoma of skin	22	2.6	60
Carcinoma of colon and rectum	33	3.3	60
Carcinoma of breast	100	6.1	79

a dissection done therapeutically as prophylactically. Conversely, when a tumor regularly metastasizes to local nodes before its presence becomes clinically appreciable, is found to involve numerous nodes of specimens examined, and not infrequently brings about death by distant spread, such a dissection must be carried out prophylactically if it is to be of any use at all. In fact, more prophylactic and fewer therapeutic dissections in such situations would in all likelihood save the most lives. More will be said of this later. It is not implied that such an appraisal can always be accurately made. Exceptions will occur but many tumors fortunately follow a fairly set pattern and if an attempt is made to understand this their behavior may be predicted with considerable accuracy. It thus becomes apparent that the problem is concerned not only with how frequently regional nodes are involved but also with how rapidly the disease is apt to spread beyond the limits of the removable chain.

NODE REMOVAL: SURGICAL CONSIDERATIONS

In many instances the anatomy may be so adaptable that removal of the primary tumor with the regional nodes becomes little more of a task than removal of the primary alone. This is true of the stomach, bowel, lung, etc. Consequently, in these there can be no question as to whether or not prophylactic dissection should be carried out, regardless of considerations such as the incidence of node involvement or the inaccessibility of the regional nodes to subsequent examination.

A closely analogous situation is presented in carcinoma of the breast. Ignoring for a moment other highly important factors, simple mastectomy with subsequent decision as to axillary dissection might well enter into the discussion were it not for the anatomic fact that clean dissection from the costoclavicular ligament to the latissimus dorsi muscle, bearing in mind the lymphatic drainage of the breast, necessitates removal of the pectoral muscles, all of which may be performed better and more efficiently on initial exposure by way of radical mastectomy. The question of node dissection, therefore, pertains mainly to those tumors in which the primary and node area are best treated separately either at one sitting or in stages. (Table III.)

Consideration must be given to the relative satisfactoriness of the several major dissections—cervical, axillary, and inguinal—based on the anatomy peculiar to each. The neck in general lends itself very well to node dissection. If the jugular vein and sternomastoid muscle are removed one finds the nodes encased in well-defined surrounding structure. In addition, a considerable length of distal lymphatic chain is removable since the clinical involvement is usually present in the submaxillary or subdigastric node areas. Axillary dissections done primarily for malignant tumors of the skin (not breast cancer) with lymphatic

TABLE III. REASON FOR NODE DISSECTIONS WITH REFERENCE TO THE PRIMARY SITE IN 160 PATIENTS

PRIMARY SITE	NUMBER OF PATIENTS	NODES POSITIVE
Melanoma, skin	34	24
Carcinoma, lip	44	35
Carcinoma, skin	25	20
Carcinoma, lower gingiva	12	1
Carcinoma, buccal mucosa	10	6
Carcinoma, tongue	7	5
Carcinoma, penis	6	2
Carcinoma, vulva	4	2
Carcinoma, anus	4	1
Carcinoma, miscellaneous	15	12
Total	161	108 (67%)

drainage to that node area, although less satisfactory than cervical dissections, nevertheless can be done with considerable satisfaction providing the arm is placed in a position to relax the pectoralis major and the scapular attachment of the pectoralis minor is divided. Radical groin dissection, however, is a rather unsatisfactory procedure from the standpoint of cancer surgery and the margin of safety is therefore narrower when involvement is present. The inguinal and femoral node groups may easily be removed with a protecting zone of tissue but the obturator and iliac nodes lie encased in a variable amount of friable fat and poorly defined areolar tissue. It would, therefore, seem reasonable to perform groin dissection with less weight of indication than might be considered necessary for the performance of neck dissection. The relative effectiveness of axillary and groin dissections is undoubtedly one of the factors involved in the poorer end results obtained in melanomas and skin cancers involving the lower extremity as compared to those involving the upper extremity or face and neck. A similar factor is probably operative in determining the poorer prognosis of carcinoma of the stomach as compared to carcinoma of the colon since the paragastric nodes are not anywhere near so neatly accessible as those draining the colon.

Not infrequently it happens that additional information gained in treating the primary tumor renders the prognosis so much poorer than was originally calculated that further treatment seems futile. Following a Miles resection for a carcinoma of the anus, for example, a pathologic report of extensive hemorrhoidal node involvement, as well as nerve and blood vessel invasion, would be sufficient evidence to discourage doing bilateral radical dissections on groins which appeared to be clinically uninvolved. Similarly, a neck dissection could hardly be expected to improve results in a cancer of the oral cavity which had stubbornly shown no inclination to yield to treatment. One might continue along this vein in the presentation of other factors which, however, pertain more to specific tumors or instances.

So far, no mention has been made of "routine prophylactic dissection," although this term is frequently encountered in the literature. It need hardly be stated that no one treating any considerable number of patients of the cancer age group will be able to perform node dissection routinely. The mortality in node dissections is not high, probably in the neighborhood of 5 per cent when

TABLE IV. REGIONAL NODE DISSECTIONS ACCOMPLISHED AS SEPARATE PROCEDURES

REGION	NUMBER	POSTOPERATIVE DEATHS
Neck (subtotal and total)*	124	10
Axilla	17	0
Groin	48	0

*Combined mandibular resection done in thirty patients.

appraising the entire heterogeneous group (Table IV). When applied to a certain poor-risk subgroup, however, it will become prohibitive. This must be borne in mind when comparative end result figures are stated to show the advantage of prophylactic dissection, for in choosing such a group a selection of patients more likely to survive a five-year period is automatically made.

To date, there appears to be little convincing factual evidence presented either for or against these prophylactic procedures. There can be little argument that cancer in lymph nodes is best treated while still in its subclinical stage. It is also true that only harm in needless operative mortality will result from operation in any group of patients whose nodes have repeatedly been demonstrated to be negative. The suspicion of metastatic nodal disease cannot be based on possibilities, for with cancer anything is possible; it must be founded on presumptive evidence. The quixotic attitude of radical advocates of prophylactic dissections will discredit such operations. Adopting the two previously mentioned principles, it then is no longer a question of whether one does or does not subscribe to prophylactic dissections for tumors of a certain organ or structure; rather, it becomes a matter of deciding which patient will require such a procedure. That decision can be arrived at only when all of the available facts pertaining to the individual case are known and weighed in understanding of the life history of the particular kind of tumor present and of its therapeutic setting. It is conceded that all such evaluations will not subsequently be proved correct, yet no surgeon today would advocate routine gastric resection for all cases of peptic ulcer, although it is conceded that fatal hemorrhages and fatal perforations will, with conservative management, occur occasionally in the hands of the most experienced clinician. The exception cannot establish the rule.

Certain definite contraindications to separate node dissection, either prophylactic or therapeutic, will readily be accepted as absolute and should require no further discussion:

(1) an uncontrolled or uncontrollable primary tumor; (2) distant metastases; (3) extremely poor general condition.

Three additional and frequently mentioned contraindications to node dissection must be considered relative rather than absolute: (1) perforation of the node capsule by disease as evidence by fixation or demonstrable invasion of adjacent structures such as skin or bone; (2) bilateral or contralateral node involvement; (3) highly undifferentiated tumors.

Exceptions to the first of the relative contraindications should include instances in which the disease has been of a low grade of malignancy and has shown a disposition to progress only locally in nodes which are still amenable to wide surgical removal. Carcinoma metastatic from the lip to the submaxillary nodes which may invade the mandible and skin provides an excellent example (Fig. 2). Under such or similar circumstances it has been the policy at this hospital to remove any involved structures which are not definitely vital to the patient.

It is less simple to outline exceptions to the second mentioned relative contraindication. In general, this one will stand when an evaluation of all factors concerned points to a very aggressive form of disease. Factors such as a less than highly differentiated (grade II to IV) primary tumor in a normally unfavorable site and/or disease present bilaterally simultaneously with a short history are exemplary. Under such circumstances there seems little doubt but that the very occasional cured lesion would be many times outweighed by the operative mortality. Especially would this be true of bilateral neck dissection with bilateral

internal jugular ligation. Carcinoma of the lip here also presents the greatest number of noteworthy exceptions (Fig. 3). Martin and associates¹³ reported 20 per cent of patients with bilaterally positive nodes surviving five years. Our own experience with such patients has also been encouraging to date.



Fig. 2.—Carcinoma metastatic to the left submaxillary lymph nodes (primary tumor of lip treated elsewhere) with ulceration through the skin and invasion of the mandible; treatment was combined jaw resection-neck dissection. Later contralateral metastases developed; treatment was supra-omohyoid neck dissection.

Highly undifferentiated tumors to which belong the majority of the carcinomas of the nasopharynx, base of the tongue, pharynx, extrinsic larynx, etc., are primarily radiotherapeutic problems because of their general radiosensitivity. In addition, metastases when they occur tend to be widespread. However, occasionally one of these is encountered in which the primary tumor has completely disappeared under treatment but the nodes have not. In the absence of any

demonstrable distant spread their removal seems to be justified as offering the only remaining chance of cure.

That surgery occupies a place in the treatment of lymphosarcoma was demonstrated in a review by Sugarbaker and Craver¹⁵ of 196 biopsied cases. Twenty-four patients had been treated by operative node removal which had



Fig. 3.—Advanced carcinoma of the lower lip fixed to the mandible and metastatic to submaxillary and submental node areas bilaterally. Treated by block resection of lip and mandible with bilateral supraomohyoid neck dissection and showing subsequent reconstruction.

usually been followed by postoperative x-ray. Six of these remained well without return of disease for five or more years. Although the number so treated was small, the results in that group were more encouraging than those derived from any other form of treatment. It is probable that patients under 30 years of age, in whom the disease is usually very active, and those with disease in more than one node area, regardless of age, should be rejected for node dissection in

lymphosarcoma. Similarly favorable results from surgery in this condition have since been reported by Gall.⁷

Practicality does not here permit a discussion of the problem as it separately relates to several of the individual tumor groups nor would this be possible since comparable figures are rarely available. It might be well to consider them, however, as they pertain to one group in which reliable data is present and over which considerable controversy has arisen—carcinoma of the lip.

Arguments proposing prophylactic dissection in cancer of the lip:

1. Eleven to twelve per cent of patients with clinically negative nodes have disease contained in them.
2. The economy of doing needless dissections cannot be computed against the life of those who survive only because they have had dissections done.
3. The operative mortality for upper neck dissections should not be more than 1 to 2 per cent.
4. Some patients will fail in their follow-up and will therefore lose their chance for cure.
5. Of patients prophylactically dissected and having pathologically positive nodes, 42 per cent⁵ survive five years.

Arguments opposing prophylactic dissection in cancer of the lip:

1. About 11 to 12 per cent¹³ of patients with negative nodes on admission will develop them later.
2. Therefore, approximately nine out of ten neck dissections will be done needlessly.
3. The operative mortality from clinics treating large numbers of patients has varied in upper neck dissections from 0.42 per cent⁶ to 6.9 per cent.⁵ This will undoubtedly be somewhat higher in the hands of surgeons doing only an occasional operation.
4. With good organization, a follow-up of 95 per cent¹³ may be attained and needed dissections may then be done as soon as nodes develop.
5. Thirty-seven per cent of patients having dissections done for nodes developing during follow-up survived five years.¹³

In consequence it would seem proper to review several factors known to influence the incidence of node metastasis in carcinoma of the lip.

1. Whether the lesion has been previously treated. Figi⁶ found positive nodes in only 4.5 per cent of all "primarily" treated patients whereas they were present in 17 per cent of all patients whose lesions were "secondarily" treated.
2. The grade of the primary. Taylor and Nathanson¹⁸ recorded a node incidence of 6 per cent in Grade I lesions, 30 per cent in Grade II, and 52 per cent in Grade III. Figi⁶ found no metastases in any Grade I "primarily" treated case.
3. The size of the primary. Martin and associates¹³ in a large series of cases have stressed this and reported a rising incidence with increasing size of the lesions in patients whose nodes were negative on admission from 3 per cent with lesions until 1 cm., to 10 per cent with lesions 1.0 to 1.9 cm., to 13 per cent with lesions 2.0 to 2.9 cm., to 26 per cent with lesions over 3 cm. in diameter.

It therefore appears reasonable, in carcinoma of the lip, to direct the effort of prophylactic removal for occult cancer only to those patients in whom sufficient indication exists, for only by this means will the number of operative deaths be reduced in patients whose nodes are later found to be uninvolved.

Attention should be called to the wide difference in five-year end results existing between patients with lip cancer who present nodes on admission (24 per cent, Martin and associates¹³) and those who develop them later (37 per cent, Martin and associates¹³) or are found to have them on prophylactic dissection (39 to 42 per cent, Figi,⁶ Eckert and Petry⁵). Allowing for a small number of patients with nodes who present hopelessly advanced disease at the time of admission, this amounts to about 15 per cent. The greater aggressiveness of the disease or late arrival of the patients for treatment is the logical explanation for this difference in survival but more important are the therapeutic implications since suprahyoid or supraomohyoid neck dissections are quite generally considered to be adequate treatment for cervical metastases from lip carcinoma. We have very carefully examined thirty consecutive dissection specimens in sixteen of which nodes were clinically positive on admission and in fourteen of which they were clinically negative but were found either on prophylactic dissection or had developed during follow-up. In the sixteen cases (nodes positive on admission) the average number of nodes involved was 3.4, and nine had more than 2 nodes involved. Among the fourteen cases (nodes negative on admission) the average number of nodes involved was 1.3 and in no case were more than 2 nodes involved. We have made a similar study in melanoma often clearing the specimens in order that the greatest possible number of nodes might be found and sectioning each node. Parenthetically it should be said that no attempt is being made to draw any general comparison between cancer of the lip and melanoma. It should be pointed out, however, that whereas no surgeon would do less than the most radical node dissection either prophylactically or therapeutically for melanoma, the quantitative node involvement per specimen was less than in the sixteen patients with lip cancer whose nodes were present on admission. Of thirteen consecutive dissection specimens in which at least one positive node was found, the average number of nodes involved was 2.8. Such a high quantitative node involvement in lip cancer in which the nodes are already present on admission and particularly when they are confined to one side of the neck should probably be met by radical neck dissection reserving the less radical procedures for prophylactic or later therapeutic dissection in which such procedures seem to be safe.

In the surgery of cancer there are, in general, two major problems which frequently demand careful consideration: first, the degree of radicalness required by the tumor and second, the degree of radicalness which the patient will withstand. Overestimation of the first and underestimation of the second will result in too high a percentage of postoperative fatalities. The converse will result in too low a percentage of cured cases. Adequate attention is usually paid to careful estimation of the patient, but experience gained at a tumor clinic from referred cases teaches that more emphasis should be placed on an estimation of his tumor, particularly as it pertains to the node status, and no decision as to the extent of the procedure required should be reached until every means of determining that status has been dealt with short of interfering with the execution of whatever procedures may be contemplated.

The declaration as to whether a dissection is being done prophylactically or therapeutically is based entirely on clinical findings. The correctness of the

original assumption is determined only when the specimen is carefully examined in the laboratory. That this assumption is frequently proved to be incorrect in the prophylactically dissected group has been amply illustrated. Neither is it unusual to dissect for what are taken to be involved nodes only to find that hyperplasia alone is present. This is particularly apt to occur when the primary tumor is badly infected. In the interests of more precise evaluation and more balanced treatment, such mistakes in diagnosis should be eliminated in so far as is possible. The employment of aspiration biopsy for suspected nodes will be of great aid in problems of such therapeutic importance. There is little need to elaborate further in this regard except to state that the material obtained from metastatic lymph nodes by this simple procedure, if similarly treated, is no more difficult to interpret microscopically than that obtained by incisional biopsy and is equally reliable since negative material by whatever means obtained, either by incision or aspiration, may be meaningless. The arguments propounded against this procedure are reminiscent of those formerly voiced against the biopsy of surface lesions and are equally theoretical. In our experience aspiration biopsy of suspected lymph nodes has been a valuable clinical aid and in the absence of unfortunate sequelae places the burden of proof of theoretical concepts directly on critics of the procedure.

SUMMARY

1. The role of the lymphatic vessels and nodes in cancer dissemination is briefly discussed.

2. It appears remarkable that prevailing opinions regarding the treatment of occult cancer in lymph nodes should remain so divergent.

3. In an attempt to shed some light on the question the factors relating to the incidence of node metastases and to node removal are reviewed.

4. The arguments for and against prophylactic node dissection are examined as they pertain to carcinoma of the lip, since comparable and reliable figures are at present available for this group alone.

5. When the results of each method of treatment are examined, it is found that the anticipated greater survival among those prophylactically dissected and having involved nodes (as compared to those dissected after the nodes have been permitted to become clinically apparent) is overbalanced by a greater number of operative deaths most of which occurred in patients whose nodes were found on pathologic study to be uninvolved.

6. Such unnecessary deaths can largely be eliminated by more careful attention to factors predisposing to node metastases reserving dissection for those in whom such factors are prominent.

7. It is further suggested that patients having carcinoma of the lip and arriving for treatment with nodes already present in the neck be given the benefit of total neck dissection whenever possible since on specimen study they are found to have approximately three times as many involved nodes as those who develop the nodes after the primary tumor has been treated or are found to have involved nodes on prophylactic dissection. It is felt that upper neck dissections have largely contributed to the poorer prognosis of the first mentioned group and should be reserved for patients who are prophylactically dissected or whose nodes develop while under close observation.

8. The employment of aspiration biopsy will be of great diagnostic aid in making such distinctions.

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EFFECT OF TOTAL THYROIDECTOMY ON EXPERIMENTAL PRODUCTION OF PEPTIC ULCER

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AMONG the generally accepted factors in the etiology of peptic ulcer, two stand out in bold relief, namely, hyperacidity and nervous tension.

Heretofore most of the regimens that have been devised for the treatment of peptic ulcer have been based principally on control of acidity of the gastric secretion. Regarding surgical treatment, gastrojejunostomy was once the procedure of choice. Later, pyloroplasty occupied that position and this in turn has been succeeded by partial gastrectomy. The fact remains that the ideal method of management is not as yet at hand. How can one escape the feeling that the sacrifice of the greater part of a normal stomach is a very high price to pay for the cure of an ulcer of small dimensions?

The practice of physicians of securing sedation of patients suffering from peptic ulcer by the use of various drugs represents an attempt to control the second etiologic factor, that is, nervous tension. Unfortunately, only too often

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the nervous mechanism of such patients fails to slow down appreciably. Is there anything else that one could do to curtail some of that drive which is so characteristically abundant?

As lethargy is a striking feature in myxedema, total thyroidectomy suggests itself as a means of swinging the pendulum in that direction. Will such a surgical procedure have the desired effect on peptic ulcer? This experimental study was undertaken to answer precisely that question.

MATERIALS AND METHODS OF STUDY

A series of five experiments was performed. Healthy adult dogs were used. They were maintained on a standard kennel diet except for the first three days following surgical duodenal drainage when a 5 per cent solution of dextrose in physiologic saline solution was administered by the intravenous route. All the operations were performed with the animals under ether anesthesia and with aseptic technique. Body weights were obtained at intervals of about two weeks following total thyroidectomy and every three days to one week after the performance of the Mann and Williamson¹ operation.

The total thyroidectomy was carried out through a midline incision in the neck. Great care was exercised in searching for the superior parathyroid glands and leaving them in situ with an intact blood supply. No attempt was made to preserve the inferior parathyroid glands.

Mann and Williamson's surgical procedure was used to produce peptic ulcer. The jejunum was divided 10 to 15 cm. beyond the ligament of Treitz. The proximal end was anastomosed obliquely to the side of the ileum about 60 cm. above the ileocecal junction. The pylorus was divided and the duodenal stump was closed and inverted. The continuity of the gastrointestinal tract was restored by an end-to-end anastomosis between the stomach and the distal end of the divided jejunum. All the anastomoses were made by means of an inner row of a continuous suture of plain No. 1 catgut for the mucosa and an outer row of interrupted fine silk sutures for the seromuscular layers.

RESULTS

The effects of total thyroidectomy in this series of experiments were consistently the same. All the dogs lost an appreciable amount of their original vigor, suggesting the presence of varying degrees of lethargy. Their hair became coarse, brittle, and sparse and their skin dry and thickened. The composite picture seemed to provide an experimental counterpart of myxedema as seen in man.

The most striking sequel of total thyroidectomy was an increase of body weight varying from 1.1 to 6.5 kg. (Fig. 1). The increments represented 8, 21, 22, 33, and 37 per cent of the original body weights of the five dogs. For example, one dog weighing 17.5 kg. at the time of operation gained as much as 6.5 kg. over a period of seventy-four days (Table I).

TABLE I. ACTUAL AND PERCENTAGE GAIN OF BODY WEIGHT AFTER TOTAL THYROIDECTOMY

INITIAL WEIGHT (KG.)	MAXIMAL WEIGHT (KG.)	GAIN OF BODY WEIGHT	
		ABSOLUTE (KG.)	PER CENT OF INITIAL WEIGHT
17.5	24.0	6.5	37
13.2	14.3	1.1	8
12.0	14.5	2.5	21
10.5	14.0	3.5	33
10.0	12.2	2.2	22

TABLE II. ACTUAL AND PERCENTAGE LOSS OF BODY WEIGHT AFTER SURGICAL DUODENAL DRAINAGE

EXPERIMENT	MAXIMAL WEIGHT (KG.)	TERMINAL WEIGHT (KG.)	LOSS OF BODY WEIGHT		
			ABSOLUTE (KG.)	PER CENT OF MAXIMAL WEIGHT	PER CENT OF INITIAL WEIGHT
I	24.0	10.7	13.3	55	76
II	14.3	8.8	5.5	38	42
III	14.5	8.7	5.8	40	48
IV	14.0	7.6	6.4	46	61
V	12.2	6.8	5.4	44	54

The dogs were observed for forty-nine, sixty-one, sixty-one, seventy-three, and seventy-four days before the Mann and Williamson operation was performed. At the time of exploration, a peptic ulcer had not developed in any case.

Following the institution of surgical duodenal drainage, the body weight declined rapidly in each case (Fig. 1). On the basis of the maximal body

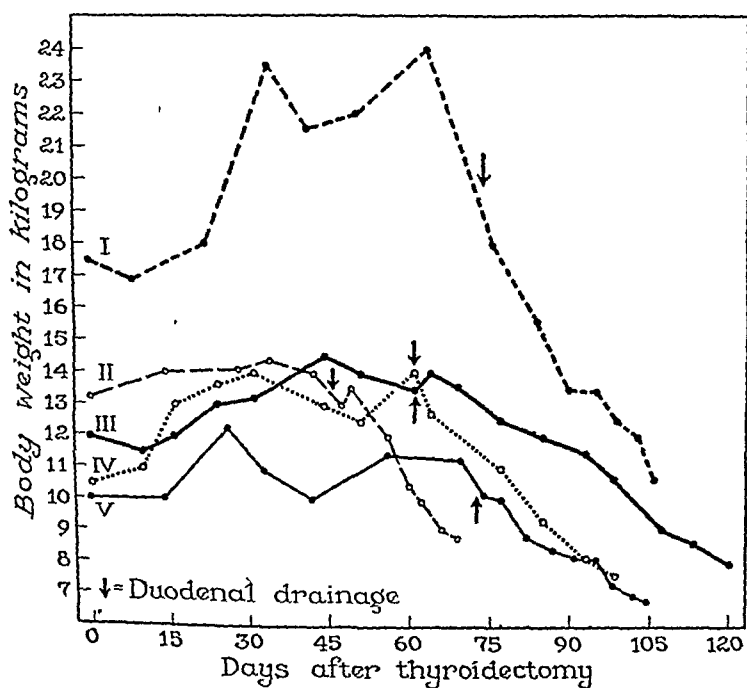


Fig. 1.—Changes of body weight after total thyroidectomy and after surgical duodenal drainage.

weight before this operation, the losses were 5.5, 5.8, 5.4, 6.4, and 13.3 kg., representing 38, 40, 44, 46, and 55 per cent of the maximal body weights of the five dogs. When the initial body weight at the time of total thyroidectomy was taken as the standard, the losses amounted to as high a percentage as 42, 48, 54, 61, and 76 (Table II).

TABLE III. SUMMARY OF STUDY AND RESULTS

EXPERIMENT	PERIOD FROM TOTAL THYROIDECTOMY TO DUODENAL DRAINAGE* (DAYS)	PERIOD OF SURVIVAL AFTER DUODENAL DRAINAGE (DAYS)	DIMENSIONS OF ULCER† (CM.)
I	74	34	2.8 × 1.8 × 0.6
II	49	28	2.0 × 1.5 × 0.6
III	61	62	2.5 × 2.1 × 1.5
IV	61	43	2.6 × 1.4 × 0.8
V	73	34	2.2 × 2.2 × 1.2

*At the end of this period there was no evidence of peptic ulcer in any case.

†A bleeding perforating chronic peptic ulcer was observed at necropsy in each case.

The dogs survived twenty-eight, thirty-four, thirty-four, forty-three, and sixty-two days following the Mann and Williamson operation. At necropsy, a chronic peptic ulcer with punched out margins and an indurated base was invariably found (Fig. 2 and Table III). It was located characteristically on the superior posterior wall of the jejunum immediately beyond the pyloric ring. Its size varied from 2.0 by 1.5 cm. to 2.5 by 2.1 cm. The shallowest ulcers were 0.6 cm. deep, while the greatest depth was 1.5 cm. The immediate

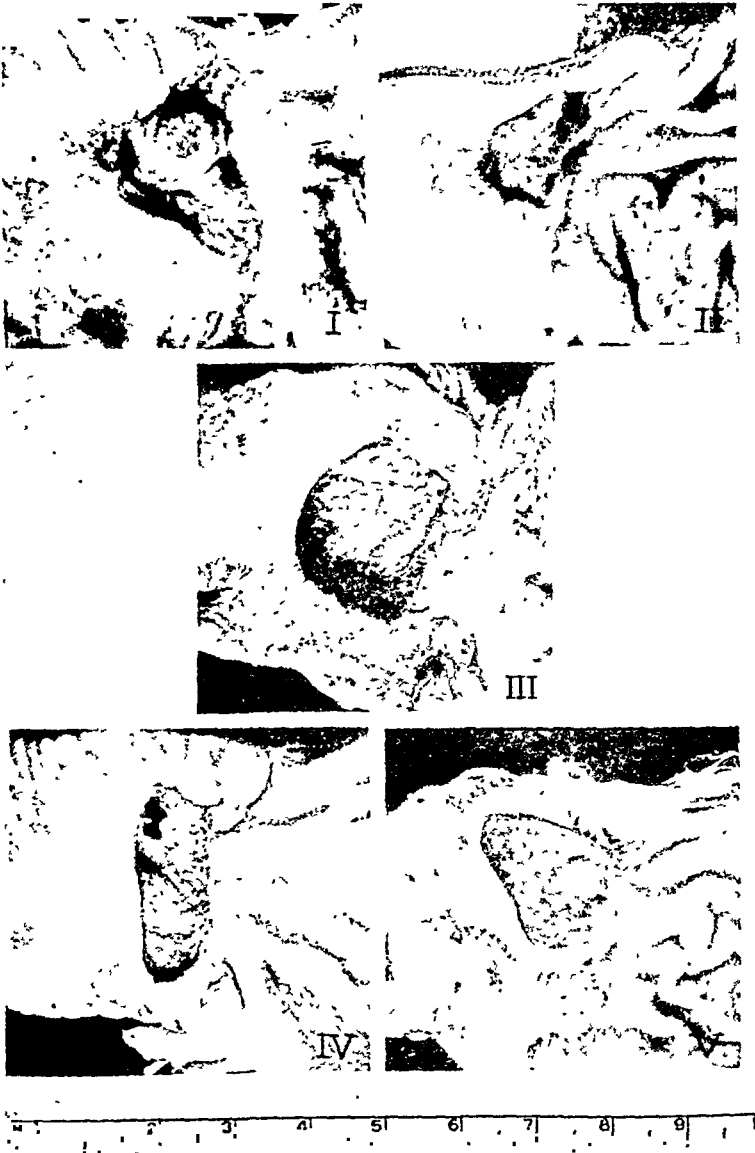


Fig. 2.—Peptic ulcers produced by surgical duodenal drainage after total thyroidectomy.

cause of death of all the dogs was a massive hemorrhage from an eroded blood vessel at the base of the ulcer. In some instances, it appeared as if perforation would have occurred had not the base of the ulcer been supported by the contiguous duodenal stump or liver to which it was adherent.

COMMENT

Experimental hypothyroidism is known to produce a decided increase in volume of gastric juice and a less marked, but nevertheless demonstrable, in-

crease of acidity.² For this reason, the dogs in this series of experiments were observed for a period varying from forty-nine to seventy-four days following total thyroidectomy but before duodenal drainage. It is interesting that in no case did a gastric or duodenal ulcer develop.

On the other hand, total thyroidectomy does seem to modify the character of the peptic ulcer resulting from the employment of the Mann and Williamson operation. As compared with my observations in other studies,^{3, 4} the ulcers are definitely more chronic, the craters being larger and deeper, and the period of survival of the dog is longer. One is tempted to speculate whether the differences might not be due in a large measure to the excessive body weight resulting from total thyroidectomy. Mann has pointed out to me, however, that the absolute and percentage loss of body weight in this series of experiments not only is greater, but also occurs more rapidly than usual.⁵

Against this background of experimental evidence, it seems difficult to understand the basis of the clinical observation that, in dealing with a patient who suffers concomitantly from hyperthyroidism and a peptic ulcer, subtotal thyroidectomy often ameliorates the symptoms due to the ulcer. However, one must admit that the abolition of hyperthyroidism does not necessarily mean the installation of a hypothyroid state. In other words, there is a rather wide range of normalcy in the activity of the thyroid gland.

The results of this study indirectly lend emphasis to gastric acidity as being the most important factor in the pathogenesis of peptic ulcer. Total thyroidectomy, although it leaves lethargy in its wake, has nothing to recommend it as a therapeutic measure for the disease.

SUMMARY AND CONCLUSION

Total thyroidectomy was performed on five dogs. No peptic ulcer developed after forty-nine to seventy-four days. Following the use of Mann and Williamson's operation to establish surgical duodenal drainage, a chronic peptic ulcer developed in all of the dogs after twenty-eight to sixty-two days. The conclusion is that total thyroidectomy does not have any mitigating effect on the experimental production of peptic ulcer.

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THE HEALING OF ARTERIES AND THE RELATIONSHIP TO SECONDARY HEMORRHAGE

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IN EARLIER experiments on repair of arteries with the use of heparin, Payr's clips were used. Later modifications of these, a small tube with a right-angled flange, were made. These methods were obviously designed to eliminate the necessity of suturing vessels and, probably what was more important, would eliminate the multiple injuries of intima at the site of suture as well as the presence of foreign body at the suture line. It was found in the course of the experiments that these aforementioned objections were of no significance when heparin was used as an anticoagulant to overcome these ill effects, namely, thrombosis at the suture line. The control of these difficulties has been described in earlier publications.¹ An interesting side line which developed out of these experiments is worthy of consideration, especially at the present time with war surgery in the forefront and with blood vessel injuries and surgery being practiced daily following war wounds. The points which we would like to consider are:

1. The effect of rigid metal or other material when applied as a circumference around an artery as demonstrated in Payr's clips and more recently in the Blakemore² tubes, etc.
2. The possible relationship of secondary hemorrhage to the effect produced by such a constricting band, or a ligature, and what method might be used as an alternative to prevent these complications.
3. The question of the survival of a venous graft bridging a gap in an artery applied in an infected field, such as a war wound.

In the earlier experiences in arteries with the clips already mentioned applied on the carotid arteries of dogs, it was found that excellent union of the vessel would occur but all the animals died of hemorrhage from the carotid artery within a period of two to six weeks. On studying these specimens, it was demonstrated that the hemorrhage occurred from a blowout of the artery immediately adjacent to the site of application of the rigid metal band. When this particular area was examined more closely, it was demonstrated that there appeared to be necrosis of the artery wall for a short distance (a few millimeters) proximal to the edge of the metal band. This appeared to have developed and to have softened so that somewhere in the third, fourth, or fifth week, the vessel gave way under the arterial pressure. On a theoretical basis, it appeared that possibly the resistance of the rigid band against the arterial pressure within the lumen was sufficient to cut off the vascular supply to the wall of the vessel through the vasa vasorum with the resulting necrosis and ultimate giving way of the wall.

It was on this evidence that it was decided that sewing up of the vessels with a suture might give better results than would the application of metal bands, etc.; our experience in many hundreds of experiments has proved this to

be true. On no occasion has the suture line shown necrosis even when applied at each end of a venous graft. These suture lines and grafts have not blown out and, as described in earlier publications,³ the only problem in these cases was the question of thrombosis at the suture lines which was prevented by the use of heparin.

On giving further consideration to these secondary hemorrhagic effects, following ligation of vessels, the literature was reviewed to determine the end results of ligation of the aorta in human beings. There is a multitude of methods described to occlude the aorta and this, in itself, was some evidence that no single method was entirely satisfactory. In the recorded cases with few exceptions, where the human aortae were occluded by ligatures, fascial bands, tapes of various sorts, and metal bands of wires, all the patients died of secondary hemorrhage within a period of a few months to one year, except in those cases dealt with by a graft described by Reid,³ in which a foreign body such as a ball of fascia or other material was inserted in the lumen of the aorta proximal to the site of ligation or occlusion. The effect of this latter method was obviously to produce a fairly large area of thrombosis and clotting, proximal to the suture line, thereby protecting it and any area of necrosis that might ensue, during the following weeks or months.

These observations seem further to support the point already made that a rigid constricting band of any sort around a major vessel may cause an area of necrosis at the site of its application.

Obviously in smaller vessels or in vessels containing a larger proportion of muscle in the wall, the results of ligation are uniformly good except perhaps in the presence of infection. This possibly may be accounted for by the fact that ligation of any of these muscular vessels causes extreme vasoconstriction which in itself would be a protective mechanism and would favor more extensive thrombosis and clotting in the region of the ligation.

With this evidence in mind, experiments were done on the aortae of dogs. In a control group, the aorta was tied off and divided between ligatures. Various forms of ligatures were used. We were aware, however, that the abdominal aorta in a dog is not as important an arterial supply to the areas distal as is that in a human being, because of the many large branches through which collateral anastomosis, and so on, takes place. For that reason the vessel in itself is comparatively smaller and more muscular than the human aorta at a similar level.

None of these vessels exploded so that the control of the experiment was not as satisfactory as had been hoped.

In many groups of animals, instead of the aorta being tied off after it was divided, the ends were sewn up neatly with arterial suture in a fashion similar to that used in anastomosis or repair of arteries, with better end results in healing.

Obviously, if the main arterial supply and, therefore, the nutrition of the periphery is cut down by war wounds of a major vessel, the natural defense barriers to infection are greatly weakened and, thereby, the growth of organisms and invasion of tissue by infection is greatly increased. It seemed, therefore, that with injury to a main artery of an extremity, one of the best methods of obviating amputation and of preserving tissue and eliminating or reducing disabling infections in the affected extremity might be provided by a restoration of the arterial supply to the part. It would seem, then, that even in the presence of an infected wound (as are all war wounds) an attempt at repair of the main artery by end-to-end suture, or, if necessary, an attempt to apply a venous graft

between the separated ends should be made, provided this in itself did not add an extra hazard from hemorrhage by the giving way of the repaired artery, the suture line, or the venous graft.

With this in view, experiments were done in which end-to-end sutures of carotid arteries in dogs were carried out and the wound deliberately infected with dirt from the floor of the laboratory. In others a segment of carotid artery was excised and this was replaced with a venous graft by the technique described in earlier publications.³ At the completion of the operation, and on some occasions before the graft was applied, the wound was deliberately infected with dirt from the floor of the laboratory and the wounds in all cases were left widely open. In the course of a few days all these wounds in both cases were suppurating and discharging large quantities of pus. There was edema of surrounding tissue. It was recognized that these surgical wounds without extensive contusion and laceration of soft tissues were not comparable to the torn and contused, lacerated wounds of bullet and shellfire and for that reason, together with the fact that repair in dogs is better and more rapidly effective than in human beings, the conditions of warfare were not accurately reproduced.

In these experiments, we observed that the repaired vessel in an end-to-end suture showed no evidence of necrosis and did not separate or blow out, and when heparin was given the vessel remained patent and circulation was carried on normally. Within a few days the surface of the vessel was granulating and within a short time the vessel together with the whole surface of the wound was a healing surface. These wounds finally healed by granulating without secondary hemorrhage.

Where venous grafts were applied, again the ends of the arteries used in the repair together with the venous graft showed a healthy appearance. Within a few days all surfaces of these vessels were granulating and eventually the whole wound had granulated and healed. In none of these did the graft show necrosis, giving way, or other evidence of secondary hemorrhage. Heparin was given in these experiments and the vessels remained patent, circulation carrying on perfectly through the reconstructed artery.

It would appear, therefore, that following injury to the main arterial supply to the head or extremities the best prospects for saving the extremity and also for preventing major complications, such as severe infection and perhaps secondary hemorrhage, might be provided by early restoration of circulation through the main vessels. Under the difficulties existing in warfare the easiest, quickest, and perhaps safest method of accomplishing this is by the application of a tube to bridge the gap between ends of the vessel and by giving an anticoagulant such as heparin. When this involves the use of a rigid tube such as described by one of us (G. M.)¹ or by Blakemore and Lord,² the repair should be considered to be only of a temporary nature. The rigid tubes either should be allowed to become occluded or should be removed and replaced by a venous graft applied by suturing or an end-to-end repair of the vessel by suturing. Even in the presence of infection, end-to-end repair of arteries and venous grafts in arteries applied by suturing survived without evidence of necrosis or secondary hemorrhage.

CONCLUSIONS

1. Rigid bands applied around the site for repair of vessels may be a menace in causing necrosis of the vessel wall. In the presence of infection the tendency to secondary hemorrhage is increased.

2. Similarly, a tight ligature around any vessel causes some modification of nutrition to the vessel wall immediately proximal to the site of ligature. In medium or smaller vessels, under aseptic conditions, this has no ill effect. However, in the presence of infection this area of necrosis may be the site from which the secondary hemorrhage may occur.

3. When it is desirable to close off a major vessel like the aorta or when a smaller vessel in an infected war wound is to be occluded, it is safer to sew the vessels carefully with a single layer of fine continuous suture. Under these conditions there is no necrosis of the adjacent vessel wall and the tendency to secondary hemorrhage is greatly reduced.

4. The possibility of reducing the number of amputations from gangrene or severe sepsis following injury to major arterial trunks of the extremity might be reduced by a reconstruction of the arterial tree by end-to-end suture or venous graft.

5. Even in an infected wound the prospect of survival of a venous graft or of an end-to-end repair of an artery is excellent. The observations being based only on experimental evidence.

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STUDIES IN EXPERIMENTAL VASCULAR SURGERY

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VASCULAR surgery may be considered the most venerable of all the surgical specialties for it began with man's first attempts to staunch hemorrhage. The report by Susrutās on the use of the ligature in 1500 B.C., to tie the umbilical cord, is believed by Warren¹ to be the first reference of its kind in the literature.

By the third century the therapeutic treatment of aneurysms by ligation of the vessel proximally and distally to the sac, followed by excision of the aneurysm, had been described by Antyllus.²

Vascular reparative surgery has a much more recent origin. The earliest report in the literature is that of Hallowell who, in 1759, repaired successfully a stab wound in the brachial artery of a man. The circumferential portion of the vessel wound was drawn over the shank of a pin and ligated.² The pin was then removed from the wound and the ligature tightened (Fig. 1).

Since Hallowell's report, myriads of contributions by experimental investigators have proved adequately the feasibility of such extensive vascular surgical procedures as anastomosis, segment transplants, shunt circulation

(Eck fistula), cross circulation, and direct transfusion. Some of these procedures are obviously of laboratory interest only, but others, such as end-to-end anastomosis or segment transplant repair of extensive injuries which might occur in the resection of a large malignancy that has invaded an important vessel, or arteriovenous aneurysms or coarctations, are of exceedingly great importance in modern clinical surgery.

Despite the seemingly obvious indications for the uses of these proved experimental procedures, very few clinical applications have been reported. There is apparently a general and widespread reluctance on the part of surgeons to attempt reparative procedures. Some of this reluctance may be due to hazy conceptions as to the optimal technique commensurate with success; some of it may be due to excessive fear of postoperative intravascular thrombosis with its possible sequelae of events; some of it may be due to the widespread belief that collateral circulation is *usually* sufficient to invalidate the need for more dramatic procedures; and finally, many surgeons may have tried various methods enthusiastically described as simple "sure fire" techniques, only to fail, and consequently are discouraged as to the relative value of all vascular surgery.

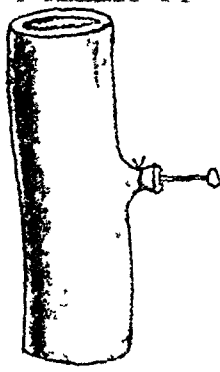


Fig. 1.—Hallowell pin method.

Because many conflicting opinions in the experimental literature do exist, and because many new factors, such as anticoagulants, have been introduced, it was decided to review the field, repeat the techniques, and, if possible, summarize the basic principles inherent in successful arterial surgery. A very short representative résumé of the history will illustrate the more common controversial points to be studied. Only those techniques which are representative of a new approach, modification, or improvement will be described.

Assmann, in 1772, repeated the technique of Hallowell in using the femoral arteries of dogs.² In a series of ten or more experiments all incisions became infected, resulting in purulent drainage, sloughing, and eventual failure of the suture, followed by either hemorrhage or thrombosis. Unaware of the significance of sepsis, he condemned reparative procedures on vessels as impractical, an opinion which apparently carried weight, for no further investigations were attempted for over 100 years until Gluck, in 1881, again renewed efforts to suture arteries.²

The first outstanding treatise on the subject was presented by Jassinowsky in 1889.² Twenty-two of twenty-six end-to-end anastomoses of the carotid arteries of sheep were successful. He stressed through asepsis and used fine curved needles and fine silk. The sutures were interrupted, placed 1 mm. apart, encompassed the adventitia and media, but avoided the intima.

Doubt as to the necessity of using interrupted sutures and avoiding the intima was raised by the favorable reports of Silverberg in 1897 and 1898.² He used the continuous over-and-over stitch, and included the intima.

The seemingly logical advantages of the mattress suture, which everts the ends of the artery and permits comparatively extensive intima-to-intima contact with a minimal exposure of suture to the blood flow, were studied by Briau and Jaboulay.²

Failure resulted in ten experiments on the carotid arteries of dogs, but success was obtained when the technique was applied to the carotid artery of a donkey. Here, then, were introduced two additional variables: the merits of the mattress stitch versus the simple interrupted or over-and-over suture, and the question of the minimal size of vessels commensurate with successful repair.

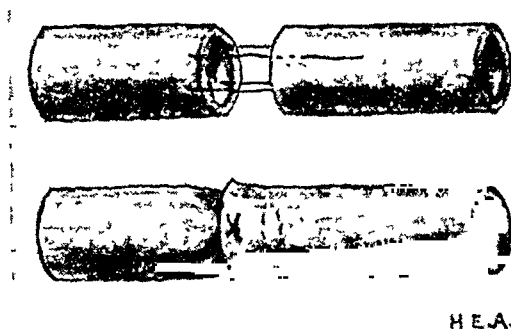


Fig. 2—John B. Murphy mattress suture technique.

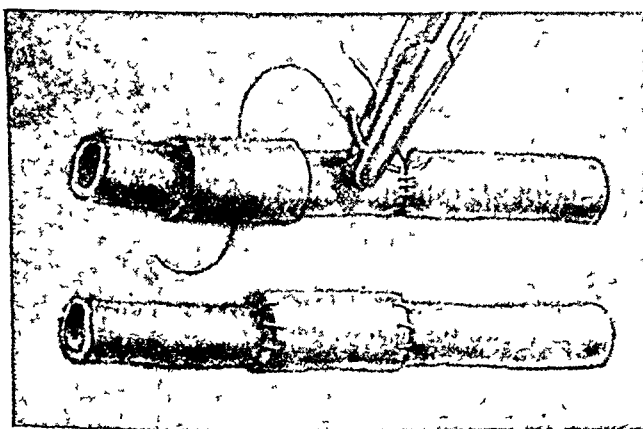


Fig. 3—Gluck's cuff method.

In 1897, John B. Murphy reported the successful end-to-end repair of the femoral artery of man by applying the technique often used for anastomosing ureters. Two mattress sutures, 180 degrees apart, are inserted first in the central end of the artery and then passed from the inside to the outside of the walls of the distal end of the artery. Consequently, the central end is invaginated into the distal end (Fig. 2). This simple technique is not uniformly dependable.

By this time there was no doubt that anastomosis of vessels, under favorable circumstances, could be accomplished. Therefore, subsequent research was devoted to the task of simplifying the procedure.

Gluck, in 1898, introduced his "cuff" method.² The cuff consisted of an autogenous segment of vein telescoped over the suture line. The cuff reinforced the suture line and helped control leakage (Fig. 3).

In 1900, Payr introduced the first version of his magnesium cannula.² It resembled a diminutive napkin ring with two grooves. The central end of the artery is slipped through the lumen of the ring and the end cuffed back and tied to the farthest groove. The distal end of the artery is then stretched over the central end of the artery and secured by a ligature placed over the nearest groove (Fig. 4). An improved version of this ring, using a perforate disk face, was later described (Fig. 5). A recent modification of the Payr ring, with an enviable record of success experimentally and clinically, is the vitallium tube technique.³

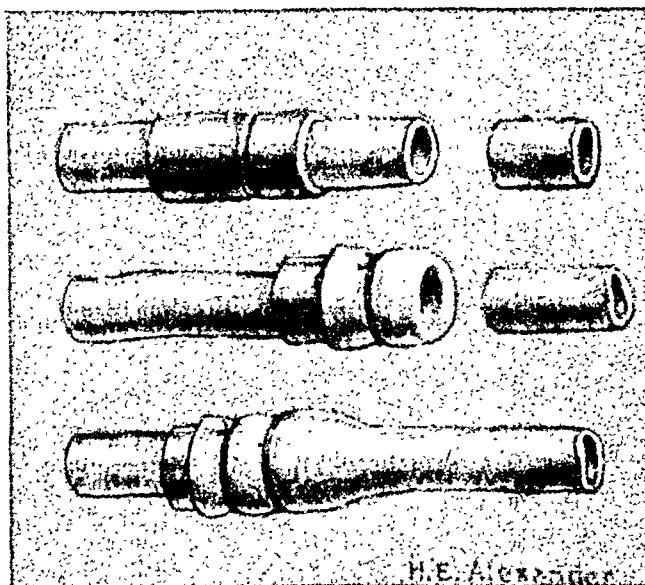


Fig. 4.—Payr ring.

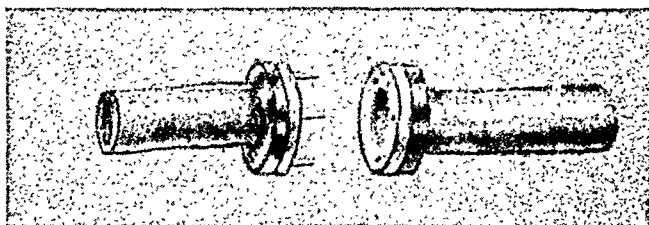


Fig. 5.—Payr's improved disk and ring.

Although by this time all of the essential principles of vascular repair had been described, it remained for Carrel and Guthrie⁴ to present the most classical example of research in the field. Their many reports, working together, and later singly, described the unprecedented limits which can be attained in vascular surgery. They did long-term follow-up studies on such fascinating subjects as auto-, hetero-, devitalized tissue, and foreign body (glass and rubber tube) transplants into the arterial system. They standardized the essential procedures and introduced their three-stay suture technique which simplified and permitted the successful repair of arteries much smaller than heretofore possible. Their results set the standards to which all others are compared.

In this method the ends of the artery are united by three interrupted sutures placed equidistantly (120 degrees) apart. The assistant then grasps any consecutive two of the three stay sutures, one in each hand (Fig. 6). Mild traction everts the ends of the artery slightly so that the surgeon can sew the segment with a straight arterial needle. After one segment is sewn, the assistant rotates the stay sutures so as to advance to the next segment until each of the three segments has been sewn in turn. The continuous over-and-over stitch is used.

Although the Carrel-Guthrie technique was a decided advancement, it still required considerable skill, not only by the surgeon but by his assistant as well. Much depends upon the steadiness and degree of tension applied to the stay sutures. Also, it is exceedingly difficult to apply the principle when working in a cavity. To circumvent these criticisms, Horsley designed and introduced a mechanical aid which he called the "Arterial Suture Staff."² This instrument is somewhat V shaped, with one leg long and the other short. The

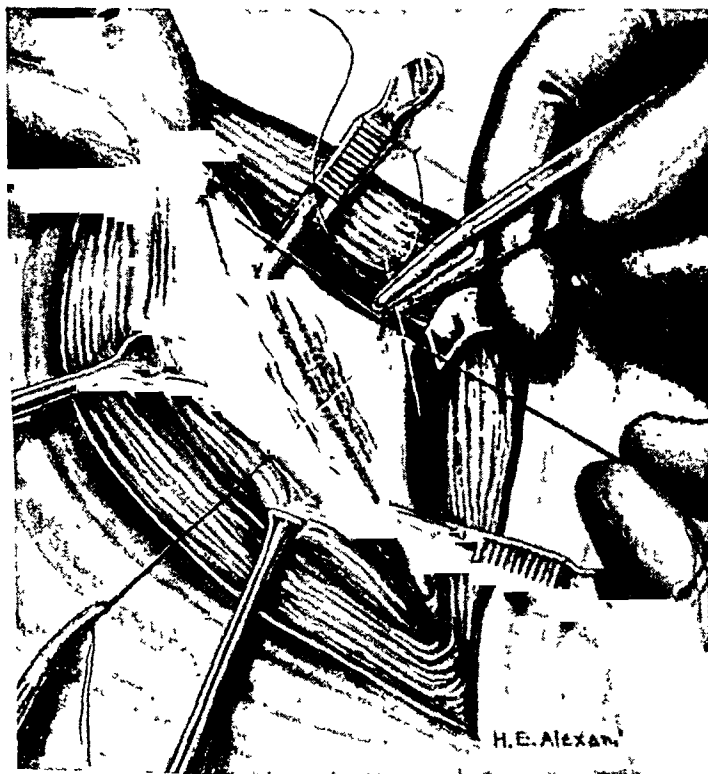


Fig. 6.—Carrell-Guthrie three-stay suture technique.

staff has projecting buttons along both shanks. The three stay sutures are fastened to the appropriate buttons, insuring constant precise tension. The trained assistant is not necessary and the staff permits work inside of deep cavities (Fig. 7).

Horsley used the so-called "cobbler" suture, which is a continuous double mattress. The thread has needles at both ends. After the first stitch is centered at one-half the length of the thread, a needle is taken in each hand and thrust through both margins of the same part of the artery, but from opposite sides (Fig. 7). The hands switch needles and the process continues.

The difficulties encountered in attempting to place three stay sutures equidistantly apart in *two* halves of a contracted and retracted distensible tube

are responsible for most of the failures in end-to-end anastomosis. If the stay sutures are not precisely placed, distortion of the two halves will result in poor approximation, leakage, and eventual failure by thrombosis.

In 1940, the soluble rod as an aid to vascular anastomosis⁵ was described. In this technique the three stay sutures are eliminated entirely. The ends of the artery are stretched and approximated *accurately* over the soluble rod and sutured by one continuous over-and-over stitch. The rod rapidly dissolves in the reinstituted blood flow. The system permits operation in deep cavities of small dimensions.

Also in 1940, Murray⁶ opened an entirely new field of possibilities with his description of the uses of heparin in experimental and clinical cases of vascular repair.

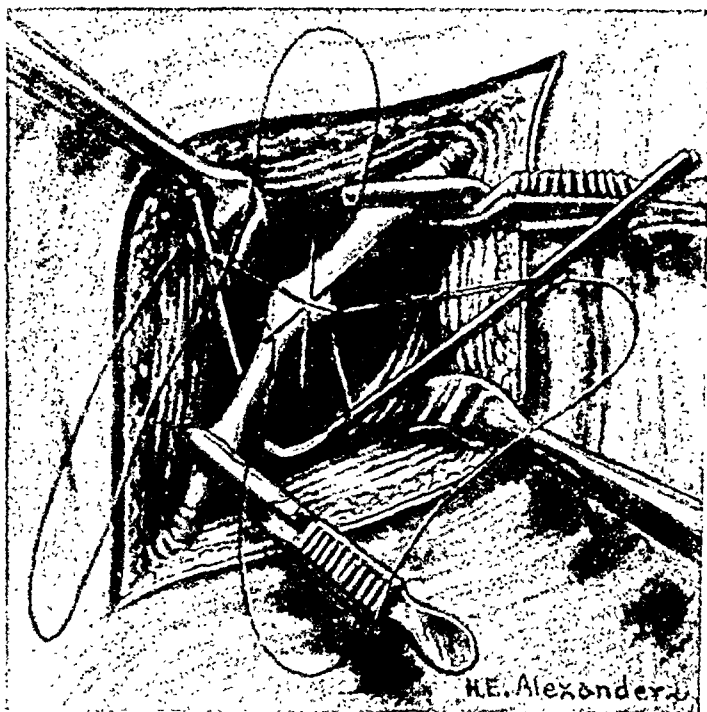


Fig. 7.—Horsley's suture staff and cobbler suture.

From this brief résumé of representative techniques we are now ready to investigate the merits of each technique and to determine and evaluate the common factors essential to success. We know that the surgical anastomosis of blood vessels is feasible and can be accomplished by many methods. What we must find out and understand are the causes and mechanism of failure.

In brief, we must consider: (1) Infection, (2) minimal size of vessel commensurate with average success, (3) coats of the vessel included in the stitch, (4) optimum spacing of the stitch, (5) optimum type of stitch, (6) evaluation of factors involved in intravascular thrombosis, (7) types of suture material, and (8) anticoagulants.

EXPERIMENTAL STUDIES

Infection.—The subject of infection is not readily adaptable to controlled research. Observations were limited to those cases in which unintentional infection had occurred. There were approximately fifteen purulent infections in over 250 experiments. Most of these fifteen were observations on techniques that were failures under ideal conditions, therefore it was impossible to evalu-

ate the significance of infection as a cause of failure. In four cases, when proved technique was used, followed by subsequent infection, three were functional and one thrombosed. In one case the infection eroded into the artery about one inch from the suture line with resulting hemorrhage and death. However, in this case the vulnerability of the artery was probably not much greater than in an unoperated artery existing under identical conditions. There is no evidence that thrombosis of an anastomosis in an infected field increases the susceptibility of the subject to a systemic bacteremia.

A thrombosed artery will often canalize after quiescence of the bacterial invasion and thus restore a favorable percentage of function. It is felt, therefore, that the existence of unfavorable conditions met with in dirty traumatic wounds should not in themselves deter attempts at restitutorial surgery. Temporary function also permits development of collateral circulation which in physiologic effect often accomplishes the same end results.

Minimal Size of Vessel Commensurate With Average Success.—The absolute limitations imposed by the physical relationship between vessel size and suture size permit the successful anastomosis of arteries far smaller than any vessel in adult man which may require anastomosing. These factors will be discussed with the physics of intravascular clotting.

I was consistently successful in my efforts to anastomose the carotid arteries of dogs of 30 pounds weight. The average outside *functioning* diameter of these vessels is slightly less than $\frac{1}{2}$ cm. Therefore, this size of artery was chosen arbitrarily as the control size for the comparative studies of techniques.

Standard arterial silk sutures* were used throughout. The sutures come in one size, but a choice of a straight, one-half curved, or full curved round needle may be had. All types were used.

Coats of the Vessel Included in the Stitch.—The artery or vein has three histologically distinct layers: intima, media, and adventitia. The intima lines the vessel and consists of flat endothelial cells. The intima is usually about two or more cell layers thick. It derives its nourishment from the blood flow within the vessel itself. The media is composed of smooth muscle and elastic connective tissue. It is thick in an artery and thin and weak in a vein. It derives part of its nourishment from minute penetrating capillary blood vessels which arise from a plexus of vessels termed the vasa vasorum. The vasa vasorum is contained in the outermost layer of the vessel—the adventitia. Besides the vasa vasorum the adventitia consists of loose areolar and connective tissue.

The main difficulty encountered in including this layer in the suture bite is that the adventitia is "sticky" and will adhere to the suture material tenaciously. As a result it will either snag the thread, causing breakage, or it will be carried by the thread into the lumen of the vessel where it tends to promote intravascular clotting. The adventitia is weak and imparts little, if any, strength to the suture line. It can be stripped back from the suture site readily. Consequently, it is not advisable to include this layer in the suture. After the suturing is completed, however, the adventitia should be worked back to its former position. This enables the vasa vasorum to reestablish nutrient connections to the media.

The question of the inclusion of the intima in the suture is limited by practical aspects. It is exceedingly difficult, tedious, and impractical to join adequately two arterial ends by sewing through the media only. With practice and patience it can be accomplished in a very large artery. I attempted many

*Supplied by Johnson & Johnson, New Brunswick, N. J., and Chicago, Ill.

times to avoid the intima, without success, except in one case. In this artery about one-half of the intima escaped the suture. When the animal was sacrificed one month later the artery was functioning, but that part of the intima not held by the suture had retracted about 3 mm., exposing media to the stream. There was an organized mural thrombus in this area. Histologic studies indicated endothelialization of this clot was in progress. The rest of the suture line was not only free of emboli, but was completely encapsulated in endothelium.

Final conclusions should not be drawn from one observation. However, in view of the severe technical difficulties presented by attempts to avoid the intima, plus the fact that almost all experimenters since Jassinowsky have included the intima, it appears evident that the intima may be included in the suture bite. In summary, the suture bite encompasses the media and intima, but not the adventitia.

Optimum Spacing of the Stitch.—The optimum spacing and type of suture was studied next. The first and immediate prerequisite of repair is that the leak be stopped. Jassinowsky first stressed the point that sutures placed 1 mm. apart will adequately form a leakproof repair. Moreover, the 1 mm. gap is the maximum space allowable for a leakproof repair, regardless of the type of stitch or the size of the vessel.

Although a continuous over-and-over or continuous mattress is less tiring than either the single interrupted or single mattress, nevertheless, 1 mm. spacing is a tedious procedure. Consequently, many methods have been applied to the further simplification of this problem. The most common method is the cuff technique of Gluck (Fig. 3). The cuff extends for a considerable distance beyond both sides of the suture line. Ideally the cuff should have an inside diameter slightly less than the maximum outside diameter of the functioning vessel to be repaired.

Leakage at the site of the anastomosis results in a fibrin seal of the ends of the vessel to the cuff. Application of the principle was tested, using many substances for cuffs. The arterial ends were approximated by six equispaced interrupted sutures. The following results were obtained.

In six cases using autogenous jugular vein segments, there was little or no leakage after one minute, but all vessels became thrombosed within one week. When rubber (six experiments), fascia (two experiments), peritoneum (one experiment), or viable muscle strands (four experiments) were used as cuffs, failure from thrombosis resulted in every instance. Recently a new product, absorbable cellulose, was used in two cases as a wrapping or cuff, with failure from eventual thrombosis. Four experiments were tried, using pure fibrinogen in concentrated aqueous solution held in a mold around the suture line. The fibrinogen was converted to fibrin by addition of thrombin. After allowing a few minutes for setting, the mold was removed and the blood flow resumed. The fibrin film was unable to withstand the arterial pressure.

Although the use of only six stay sutures is admittedly a radical experimental procedure, nevertheless, the failures emphasize the fact that most failures in vascular reparative surgery are due to latent intravascular thrombosis. Moreover, these embolisms present the typical gross and histologic appearance characteristic of propagating thrombi. The clot is always adherent to one part of the suture line but may have multiple points of attachment, usually at areas where the intima has retracted, exposing media or adventitia.

Some thrombus formation occurs in any suturing process, for there is always some initial oozing from the needle holes which ceases in about one

minute. But these sealing clots are within the wall where they become organized rapidly without interfering with the re-endothelization of the suture line.

Fig. 8 shows a typical example of the absence of mural thrombi in a successfully anastomosed artery. On the left is the segment taken three days after anastomosis. The sutures are distinct. On the right is a segment from the opposite carotid artery of the same animal taken some six weeks post-operatively. The sutures are completely covered with endothelium.

It is felt that the control of initial bleeding by a cuff creates false security. However, new possibilities in their application have been created by the use of anticoagulants, and these will be discussed under that heading.

Optimum Type of Stitch.—I was unable to obtain successful end results using the baseball stitch. Thrombosis eventually occurred. The cause for this is undetermined to date.

The Connell stitch, in my hands, could not be placed with the required precision and was quickly abandoned. Both of these methods were attempted only as part of the general research into suture techniques.

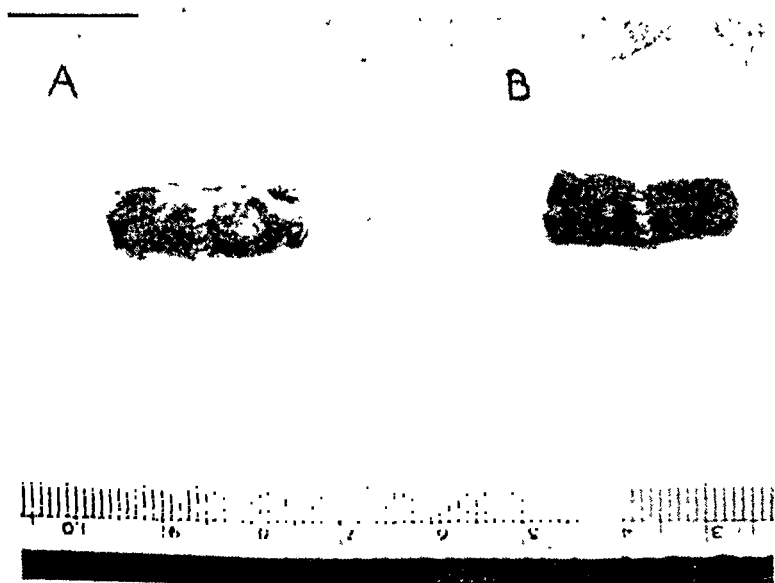


Fig. 8.—A, Three days postoperatively; B, six weeks postoperatively.

The simple continuous over-and-over is by far the easiest stitch to place and, in my hands, gave the best results. The continuous mattress and the cobbler suture are a little slower and more difficult to place neatly, but when properly executed, give dependable results. Single interrupted or interrupted mattress sutures may be used, but the process is exceedingly and unnecessarily tedious.

Two arguments are presented persistently in favor of the mattress or cobbler suture. First, the mattress affords a more secure bite which minimizes the tendency for the suture to pull through the tissue. Second, the mattress suture exposes less foreign material to the blood flow and minimizes tendencies toward intravascular clotting.

The first argument has some merit. It is quite true that the mattress suture has less tendency to cut through friable tissue as is encountered in old sclerotic arteries. Aside from this, there are no other practical advantages.

The second argument has persisted so long on a purely philosophical basis that it was decided to devise some experiments which might determine quantitatively the part the foreign body plays in intravascular clotting.

If a fine strand of silk is threaded through an artery at right angles to the blood flow, a tiny clot forms on the thread in the center of the stream which will grow slowly at first but with an ever-accelerating speed, until it occludes the lumen completely and the vessel thromboses. The clot grows from the center of the thread outward to the periphery of the vessel. However, if the same amount of a fine silk strand is placed along the longitudinal axis of the vessel so that the thread hugs or recesses into the intima, *no thrombus* will form, and in time endothelium will grow over the suture and encapsulate the thread.

If the thread is permitted slack so that it does not, in its entirety, lie uniformly adjacent to the intima, but parts of it wave idly into the blood stream, a propagating clot will again form. A propagating clot will also form, regardless of the position of the thread, if the thread is large enough to create turbulence in the blood flow.

It is evident, therefore, that the position of the foreign body with respect to the blood flow and the size of the material is of great significance.

I have applied both sewing techniques with success, but do not feel that the mattress suture has sufficient practical advantages to encourage its use over the much simpler and easier manipulated over-and-over stitch.

Evaluation of Factors Involved in Intravascular Thrombosis.—In the previous experiments the recording of data from comparative tests was of chief concern. However, it was desired to visualize some of the mechanisms at work.

A model circulatory system, made mainly of glass, was constructed (Fig. 9). The reservoir was attached to the glass tube by a flexible rubber hose which permitted changes in head pressure by raising or lowering the reservoir. One section had a venturi-like constriction, representing approximately a 40 per cent. reduction in cross-section diameter. Three small spurs opened into this section. One spur was placed before the constriction, one in the throat, and the third one in the tube past the constriction. These spurs could either be opened to place material in the lumen of the tube, or they could be connected to gages or stand pipes to register pressure changes. Citrated dog's blood, diluted with three volumes of normal saline solution, was used to charge the system. The speed of flow was regulated by adjusting the height of the reservoir.

With the system at rest, the formed elements gravitate to the dependent parts, but as soon as motion is imported, two distinct phases of flow are observed.⁷ The formed elements aggregate into a compact core to form the axial phase, while the clear fluid uniformly surrounds the core to form the peripheral phase. The axial phase moves at a much faster rate than the peripheral phase. Under uniform flow, none of the formed elements penetrate the clear zone of the peripheral phase and consequently formed elements are not *normally* in contact with the vessel wall. Essentially these observations are in agreement with those of Aschoff.⁸

If a small thread is introduced into the tube through a spur, it is apparent that it may rest entirely in the peripheral phase and none of the formed elements will strike it (Fig. 10). Moreover, if the thread is small enough to remain in the clear zone, there is little evidence of turbulence. However, if the thread, either because of its size or its extreme length, projects into the axial phase, pronounced turbulence will occur.

Another phase of intravascular clotting was observed at the same time, as follows: When the fluid entered the mouth of the venturi-like constriction there was no loss in phase characteristics. The speed of the stream increased,

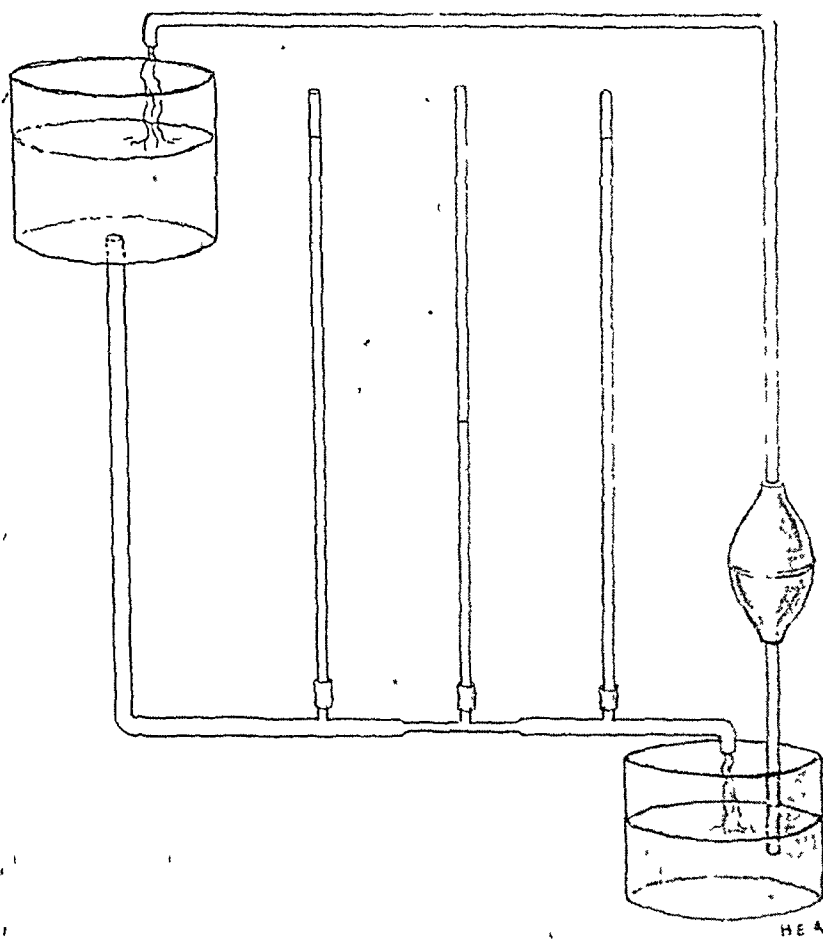


Fig. 9.—Diagram of model circulatory system

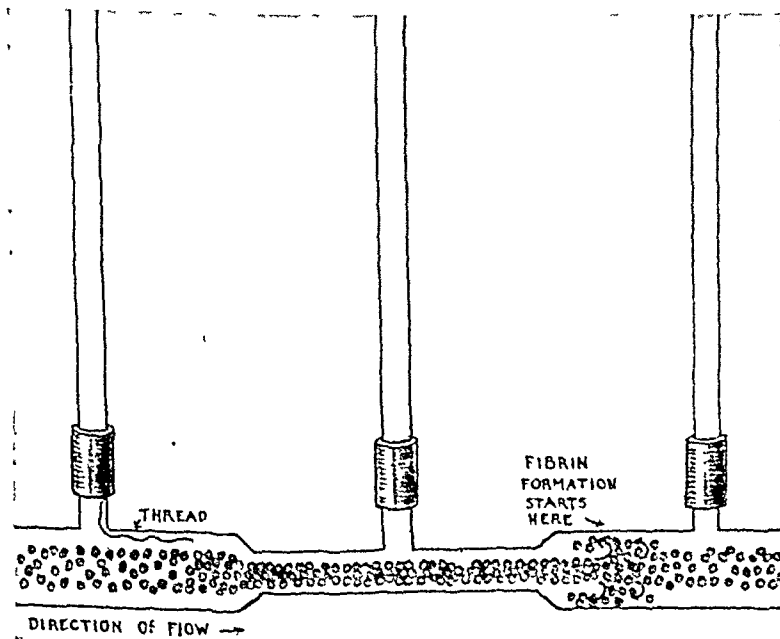


Fig. 10.—Diagrammatic illustration of two-phase blood flow and factors producing turbulence.

the clear peripheral zone was reduced in size and depth, and there was a reduction in lateral wall pressure. This is the well-known "Venturi" principle. (See any physics textbook.) When the stream emerged from the constriction there was a pronounced change which varied in intensity with the initial speed of flow. The greater the initial speed of flow, the more violent was the change. The change consisted of inversion of phase at a spot somewhat distal to the end of the constriction, the exact space varying again with the speed of flow. At this spot the axial stream struck the side walls of the tube and there was pronounced turbulence with a backward flow of cells, just as there are eddy currents behind an obstruction or a jetting stone in a fast-moving stream (Fig. 10). If small amounts of calcium chloride were added in graduated amounts to the reservoir to neutralize the citrate solution, a critical point was reached in which the blood at rest did not clot. However, prolonged agitation started the clotting chemistry. Consequently, at the point of maximum turbulence distal to the constriction it was possible to produce a very filmy propagating clot. The embolism was filmy due to the very great dilution of the blood, 3:1. This clot had a tendency to propagate against the stream.

The possibility that partial occlusion or distortion of a blood vessel could produce a propagating embolism lead to the following experiments. A single silk ligature was placed around the carotid and femoral arteries and jugular and femoral veins. The ligature occluded the diameter approximately 50 to 60 per cent.⁹ Results of single partial ligation were definitely not conclusive. There was only one occluded propagating clot in an artery and one in a femoral vein. In the artery, however, the point of attachment of the clot was in the exact relative position distal to the occlusion as the propagating clot produced in the glass model. Due to the similarity of conditions imposed and the mechanism involved, the observation was of interest even though coincidence may have reduced the significance of the phenomenon. Further studies were conducted to determine the role of the intima in intravascular clotting.

A series of carotid and femoral arteries and jugular and femoral veins were crushed by clamping in an Ochsner forceps. After crushing, the injured area was teased in order to permit re-establishment of flow.

In a series of approximately ten experiments there were no occluding thrombi found one week to ten days after the initial injury. In the case of the arteries a pronounced aneurysmal bulge had occurred at the point of injury. Histologic study disclosed that the intima had regenerated and that healing, in general, was progressing by the usual means.⁷ If an extensive area of the vessel, or even the intima alone, is damaged severely, then the regenerative processes cannot recoup fast enough and the vessel breaks down, resulting in thrombosis. Apparently thrombosis results from an *intensity* \times *extent* formula in which both factors must be present.

The observations from these experiments help to explain the observed facts that when good approximation is obtained with fine, close suturing, no intravascular clot will form and the anastomosis will be successful.

Types of Suture Material.—The question of suture material itself was studied. No actual anastomoses of arteries were attempted with catgut. No catgut of a suitable size comparable to 000000 silk is obtainable. However, the following experiments which were performed by Potts and Smith in their joint studies on pulmonary embolism help to shed some light on this subject. The femoral vein of a series of twelve dogs was ligated. On one side silk was used and on the other side plain single 0 catgut was used. In an exploratory operation one week or ten days later, it was found that the femoral veins tied with

the catgut in all cases were thrombosed. On the other hand, there were two thrombi found in the veins occluded with the silk ligature. When the silk ligature was removed in the remaining ten, re-establishment of the venous flow continued in an uninterrupted manner. This series of experiments was interrupted by the enforced dissociation of the two surgeons by World War II and, consequently, is not complete.

A preliminary opinion, however, may be ventured to the effect that catgut ligation tends to produce thrombus formation and intravascular clotting, whereas ligation with silk does not have such marked tendencies. Apparently, catgut would not be a suitable material for arterial repair even if it existed in the necessarily small sizes.

Anticoagulants.—The excellent and extensive work by Murray^{6, 10} indicates the value of anticoagulants in experimental or clinical vascular surgery. Obviously, the ability to control at will the clotting mechanism of the blood enables the operator to circumvent or ameliorate those factors which lead to postoperative thrombosis and failure.

For example, a repair executed under technical difficulties which lead to excessive intramural thrombus can be tided over the crisis by maintaining anticoagulation therapy during the essential process of organization and re-endothelization.

Especially is this use of inestimable value when performing venous segment transplants into arterial defects. Under the most ideal of conditions as to matching of the diameters of the venous segment and the artery, there will still be turbulence in the blood flow through the segment due to the "ballooning" of the weak, thin-walled vein. A vein segment in effect becomes an aneurysm and, as such, is subject to the identical reparative processes characteristic of the healing of aneurysms.

In brief, concentric mural fibrin deposits will tend to narrow the lumen and adventitial hyperplasia will tend to strengthen the weak media. Some fibrin deposits are desirable in that they re-establish smooth continuity of the conduit, but once this has been attained it becomes desirable to stop the clotting mechanism so that organization and endothelization completes the repair. By the same mechanism, the Gluck cuff has a greater opportunity for successful service.

Therefore, anticoagulants should not be considered as substitutes for surgical skill, but their value, both intrinsic and moral, must not be underestimated.

I used chlorazol fast pink¹¹ in my work in this field. Inasmuch as this dye is not in general favor for human use, the reader is referred to Murray's works for directions in the use of heparin.

DISCUSSION

The magnesium rings of Payr and the vitallium tubes of Blakemore and co-workers were not experimented with. I have seen satisfactory evidence of the Payr rings in use and the vitallium tubes give even greater promise of the ultimate in simplification of end-to-end and segment transplant. The rings or tubes are not adaptable to lateral or stab wound repairs as are the suture methods.

There is one point stressed by every experimenter in this field which is again repeated here for added emphasis. *Even though thrombosis may occur postoperatively, the process is a slow one which admits of the establishment of adequate collateral circulation.* Consequently, the end result physiologically is

the same as though perfect *technical* results had been obtained. To paraphrase a common paint slogan, "*Save the blood supply and you save all.*"

There are only a few technical fundamentals which must be adhered to: (1) Use fine arterial needles and silk (6 zero); (2) keep the suture gap less than 1 mm.; (3) approximate ends accurately; (4) use anticoagulants freely but judiciously; and (5) use mechanical aids when possible.

Under this heading comes the soluble rod technique. I am indebted to it for the acquisition of the technical skill necessary for the review presented in this paper. Because the soluble rod does definitely facilitate vascular surgical anastomosis, a condensed review of its preparation follows. Dextrose is heated slowly to 160° C. The slightly caramelized liquid is poured (or sucked) into sterile rubber tubes, the inside diameters of which approximate the functioning diameter of the artery to be repaired. The filled tubes are then cut into

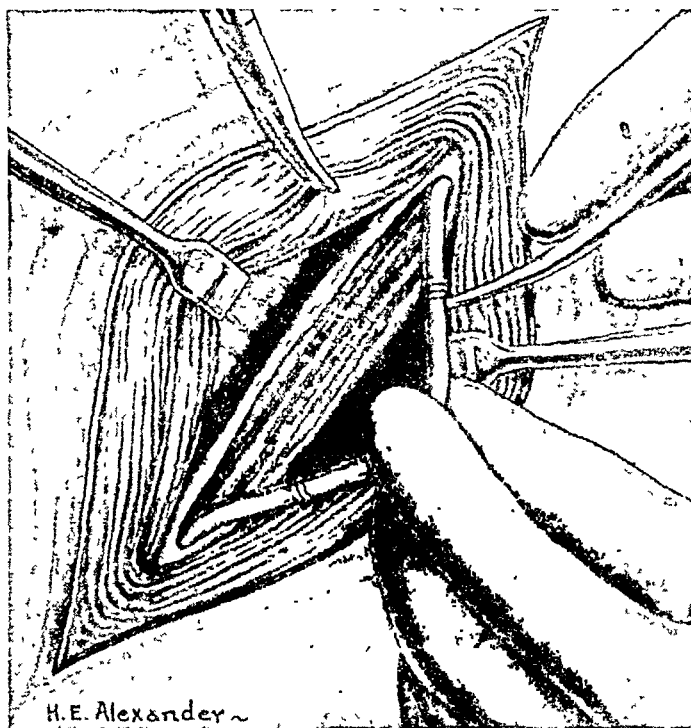


Fig. 11.

Figs. 11 to 15.—Steps in the soluble rod technique.

segments 3 cm. long. These segments are dropped into ether for a few minutes. The rubber softens and swells, permitting the dextrose rod to be slipped out of the rubber mold with ease. The rods are then coated with some substance that will serve to protect the intima from the dehydrating action of the dextrose. Paraffin, with a 50° C. melting point, makes a satisfactory coating substance which in the small amounts used (0.02 c.c.) probably presents no practical dangers from oil emboli. Recently a gelatin coat* has been experimented with. This is still in the experimental stage.

Technique of Blood Vessel Suture by Aid of Soluble Rod.—The vessel to be sutured is isolated from the surrounding tissue by packs moistened with warm physiologic solution of sodium chloride. The adventitial coat is stripped back from each end of the artery for a distance of 1 cm. The lumen is washed out with physiologic solution of sodium chloride.

*Produced by Gelatin Products Co. of Detroit, Mich.

The continuous suture technique is used. After the first suture is placed, but before it is tied, the soluble rod, corresponding in diameter to the lumen of the functioning vessel, is inserted one-half its length into one end of the artery. As the suture is being drawn tight preparatory to tying, the other end of the artery is worked over the protruding half of the soluble rod, thus approximating both halves accurately, without using stay sutures (Figs. 11 to 15).

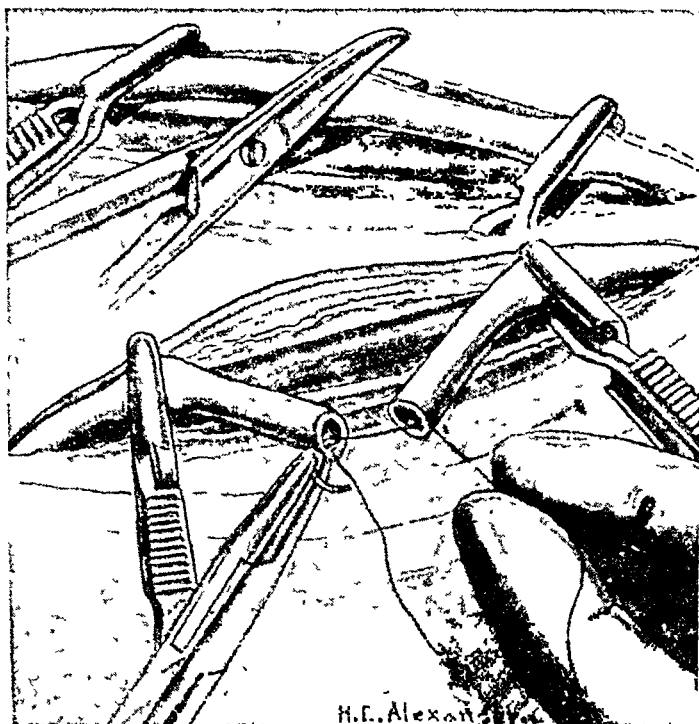


Fig. 12.



Fig. 13.

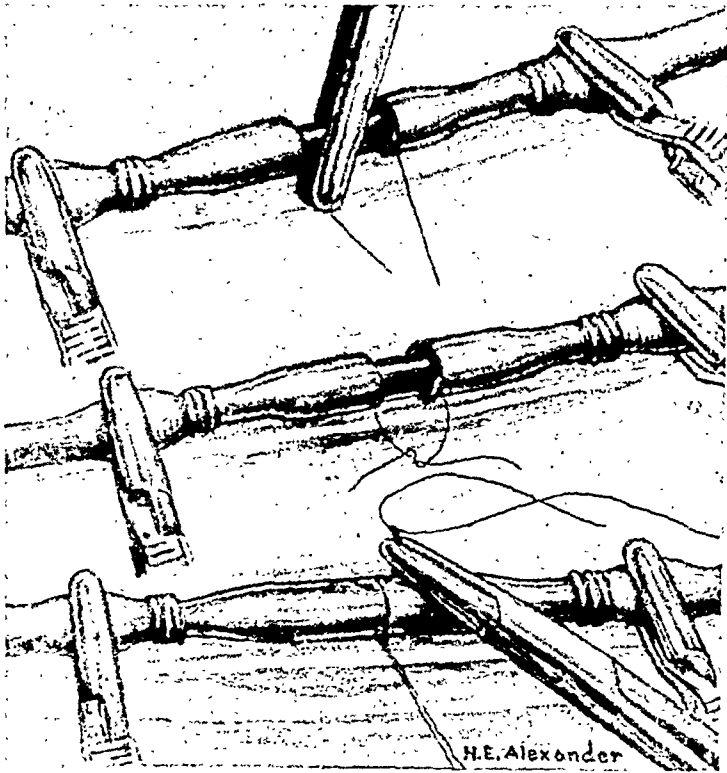


Fig. 14.

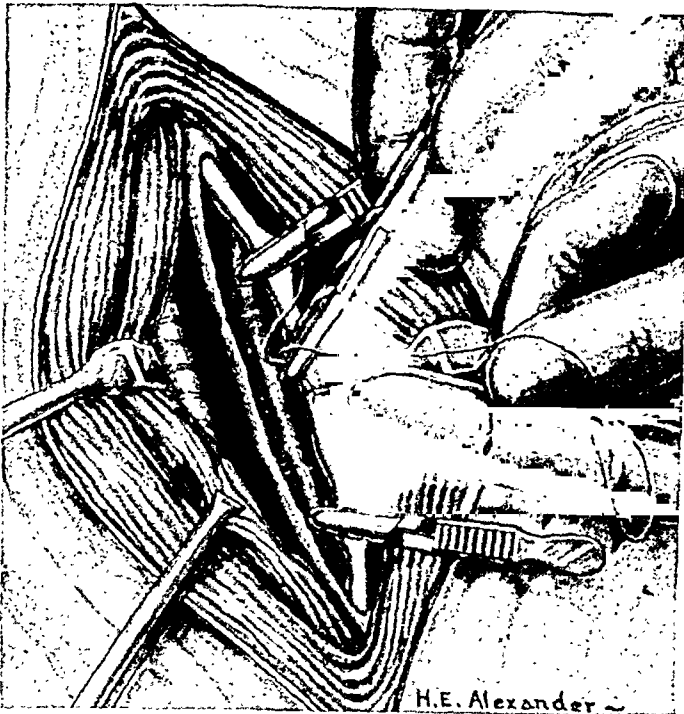


Fig. 15.

The suture is then tied. The free end of the thread is trimmed off, and the continuous over-and-over suture completes the anastomosis. Originally the straight needles were used, but the newer atraumatic half-circle round needle* has been substituted with more ease of handling. The continuous sutures are

*Supplied by Johnson & Johnson, New Brunswick, N. J., and Chicago, Ill.

placed 1 mm. apart and 1 mm. or less from the ends of the artery. Mild tension is maintained on the thread during this process in order to prevent the sutures from loosening between each sewing maneuver. The site of the anastomosis is then held lightly between the thumb and the index finger while the proximal clamp is removed. A warm saline solution pack is applied over the rod to melt the protective paraffin coating. The rod goes into solution in the pulsating blood in one minute or less. The peripheral clamp is then removed, re-establishing the circulation. Some slight oozing of blood from the suture holes and from the area between the sutures occurs immediately on release of the clamps, but this bleeding subsides within one or two minutes. After the oozing has completely stopped, permanent re-enforcement is obtained by suturing the arterial sheath securely around the artery at the site of the anastomosis.

CONCLUSIONS

It is not the province of this paper to discuss the clinical applications of the procedures described herein. It is felt that a sufficiently extensive résumé of the field has been made with experimental evidence presented in support of those procedures which can be done and those which cannot be done. It is hoped that the evidence favors predominantly the fact that anastomosis of arteries (or veins) is a feasible procedure when fundamental principles are adhered to. It would most certainly defeat the purpose of this paper if the impression were created that vascular surgical procedures are "stunts" requiring special skill. Finally, it is stressed that there is nothing to lose in attempting reparative procedures and often much to gain.

SUMMARY

1. A brief résumé of the representative techniques of blood vessel anastomosis was presented.
2. The techniques were repeated under control conditions and comparative observations made.
3. The basic principles inherent in success or failure in vascular anastomosis were studied.
4. The soluble rod technique was represented.

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It is impossible to evaluate accurately the importance of sympathetic block and sympathectomy in these cases. These procedures were of no avail in our earlier patients having ligations, and without striking benefit in the three cases reported. There is sufficient theoretical reason to believe that sympathetic injection has enough merit to justify its continued use.

The relative importance of thrombectomy and relief of arterial spasm by lumbar block and the periarterial sympathectomy in Case 3 is unknown, but it is believed the former was the more important factor in the result obtained.

SUMMARY

1. Ligation following injury of the popliteal artery results in a high incidence of gangrene requiring amputation.

2. Three cases, in which there was traumatic interruption of the popliteal artery and in which suture was done with apparently favorable results, are presented.

MULTIPLE ARTERIOVENOUS ANEURYSMS

REPORT OF A CASE OF FOUR ARTERIOVENOUS ANEURYSMS IN ONE INDIVIDUAL

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TRAUMATIC arteriovenous aneurysms, although relatively rare in civil practice, occur surprisingly often among wounded military personnel in World War II. The diagnosis is ordinarily not difficult to make. Many cases will go unrecognized for long periods of time, however, unless great care is exercised to include in the examination auscultation and palpation in the neighborhood of each wound for the presence of bruit and thrill. Nor should the examination be concluded with the finding of one arteriovenous fistula. It is not a rare occurrence for multiple fistulas to be present in a single individual. Undoubtedly the numerous small shell fragment wounds which result from high explosive shells, grenades, land mines, bazookas, etc., account for the multiplicity of vascular lesions.

Elkin* has recently called attention to this fact in reporting a patient who had three arteriovenous fistulas in the two posterior tibial vessels. I wish to present a case in which four arteriovenous aneurysms occurred in a soldier, two of them associated with a small saccular aneurysm. Diagnosis of a single arteriovenous fistula was made for the first time two and one-half months after injury and the remaining arteriovenous communications were not recognized for some time. This case is of interest not only because of the multiplicity of the arteriovenous aneurysms, but also because it serves to emphasize the necessity for extreme thoroughness in examination and operative treatment of such patients.

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*Elkin, D. C.: Arteriovenous Aneurysm; Report of an Unusual Case, Bull. U. S. Army M. Dept. (No. 84) pp. 104-106, 1945.

CASE REPORT

The patient, a 22-year-old sergeant, was admitted to Mayo General Hospital Nov. 7, 1944. Prior to Aug. 16, 1944, he had always had good health and no vascular complaints. On this date, in southern France, he was wounded by fragments from an exploding land mine, receiving multiple soft tissue injuries of both thighs, legs, feet, and of the back. At the same time he sustained a compound comminuted fracture of the right fifth metatarsal bone. There was little or no bleeding. His wounds were dressed, casts were applied to both legs, and he was transferred by ship to a station hospital in Italy. The cast was removed from the left leg September 1 and from the right November 1. He was found to have some weakness of extension of the right foot, paralysis of the right toe extensors, hyperesthesia of the dorsal surface of the right toes, and hypesthesia in the left saphenous distribution. He was returned to the Zone of the Interior and was admitted to a general hospital, October 31. Here the neurologic findings in the right foot were confirmed. The fracture was found to be healed. In addition, for the first time, it was noted that there were signs of an arteriovenous aneurysm anteriorly in the distal portion of the right leg. For this reason he was transferred to the Vascular Center at the Mayo General Hospital.

The patient had few complaints. He stated that he had some weakness of extension of the right foot and toes and occasionally a slight burning pain on the dorsal surface of the right foot. The hyperesthesia had disappeared. He had a little residual hypesthesia along the left internal malleolus. He had noted no color changes, no venous difficulties, no trophic changes, no precordial distress, dyspnea, nor cyanosis. He said that the right foot was somewhat warmer than the left and that sweating was excessive in both feet.

Examination on admission confirmed the impression of arteriovenous aneurysm in the region of the right anterior tibial vessels. A subsequent more careful examination led to the impression that he had two other arteriovenous communications. The vascular examination revealed that there was slight cyanosis of the toes of both feet in dependency. The peripheral arteries were not tortuous or thickened. The veins of the right foot were somewhat better filled than those of the left, and venous filling time was five seconds in the right foot, fifteen seconds in the left. There were no dilated or thrombosed veins. Sweating of both feet was moderate and slight pitting edema was present in the right foot and leg. There were no trophic changes. No neurologic changes were noted except for a small area of hypesthesia over the left internal malleolus, loss of extensor power in the right toes, and some weakness of extension and of eversion of the right foot. About 10 cm. above the right internal malleolus between the tibia and fibula anteriorly there was an abnormal pulsation and a continuous thrill and bruit. The bruit was audible down into the foot and up to the knee. Direct pressure over the anterior tibial vessels in this area obliterated the thrill, pulsation, and bruit, and caused a drop in pulse rate from 72 to 67 per minute. With this fistula occluded, however, there remained a loud continuous bruit which was audible posteriorly in the calf about 20 cm. above the malleoli. There was no thrill in this area. The bruit here could be obliterated by rather broad pressure against the calf muscles proximal to the point of maximal bruit. About 20 cm. above the malleoli on the posterior mesial aspect of the left leg a continuous thrill could be felt and a continuous bruit was heard. This bruit could not be obliterated by pressure in this area but ceased when the popliteal artery was compressed. The blood pressure varied from 126/72 to 116/76. With occlusion of all pulses in both legs no change in blood pressure occurred but the pulse rate dropped from 84 to 68 per minute. Skin temperatures of the toes of the two feet were about equal. On one occasion in a room at 22° C. the temperature of the toes of both feet varied from 22 to 23 and on another occasion from 32.5 to 35.5. When reactive hyperemia was carried out with the anterior tibial aneurysm occluded there was a good flush of the toes which began in twenty-five and was complete in fifty seconds. The patient had 150 healed wounds, most of which were very small and the majority of which were scattered over both legs, feet, and thighs (Fig. 1). X-rays of both lower extremities showed numerous small metallic fragments dispersed through the soft parts (Fig. 2). When the patient returned from a brief furlough he complained of some discomfort in both calves on walking and of swelling of both ankles. Examination revealed some edema of both ankles and the circumference of the right was 2.5 cm. greater than that of the left.

It was felt that the patient had three arteriovenous aneurysms, one involving the right anterior tibial vessels and the other two probably involving the right and left posterior tibial vessels.



Fig. 1.—Photographs taken after completion of the operations. The numerous small wounds are shown.



Fig. 2.—Photographs of x-rays showing the mahy tiny metallic foreign bodies present.

On Dec. 29, 1944, the anterior tibial aneurysm was explored and a double fistula, each about 4 mm. in diameter, was found between the anterior tibial artery and two anterior tibial veins, one of which lay on either side of the artery. These vessels were resected between ligatures and the aneurysm was excised. The patient did well postoperatively, showed no evidence of vascular insufficiency, and the collateral circulation was sufficiently good so that a dorsal pedal pulse was strongly palpable in the right foot immediately after operation. On Jan. 8, 1945, an exploration was made through a posterolateral incision in the left leg. The posterior tibial and the peroneal veins were considerably dilated and communicated through two channels, while the posterior tibial vein itself communicated through a fistula about 5 mm. in diameter with the posterior tibial artery which itself exhibited a saccular aneurysm on the side of the artery opposite the communication. This saccular aneurysm was well organized and was approximately 1 cm. in diameter. The patient had no difficulty following excision and on Feb. 12, 1945, the right calf was explored for the third aneurysm. The posterior tibial artery and vein were exposed through a posteromesial incision. Both were of normal size and appearance and no thrill was present. On palpation beneath the gastrocnemius it was discovered that there was a continuous thrill on the posterior aspect of the soleus muscle somewhat mesial to the operative wound. The patient had such large

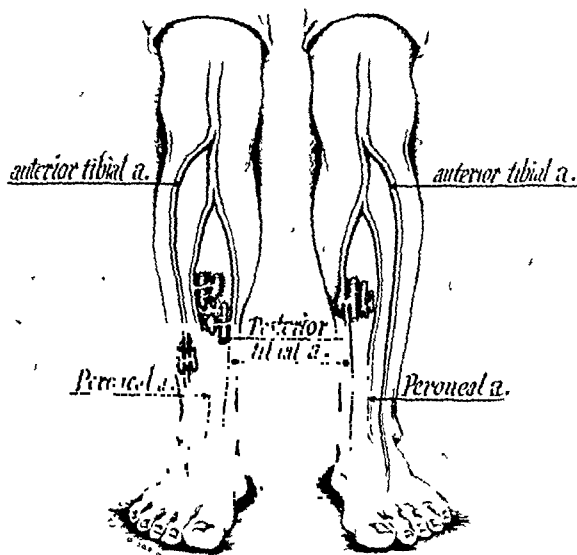


Fig. 3.—Diagrammatic sketch showing the location and general appearance of the aneurysms. No effort has been made to draw the lesions to scale. (Drawings made by T/5 A. Ossario.)

well-developed muscles that this area was not accessible through the incision and, consequently, a second longitudinal incision was made posteriorly directly over this area. The gastrocnemius was divided in the direction of its fibers and the soleus was exposed. Within the body of this muscle was found a small artery about the diameter of a matchstick which communicated with a vein about twice its size through a small saccular aneurysm 1 cm. in diameter. These vessels appeared to be muscular branches from the posterior tibial vessels. The aneurysm and the communicating vessels were excised, the artery and vein being ligated proximally and distally. The thrill and bruit in this area disappeared. Much to my surprise, however, a fairly loud continuous bruit remained somewhat lateral to and cephalad to the incision. Again this area was not accessible through the incision because of the bulk of the muscles and a third longitudinal incision was made somewhat higher along the posterolateral aspect of the calf. The fibers of the gastrocnemius were separated and the soleus was exposed. In the body of this muscle a small artery was found communicating through a fistula with a vein dilated to a diameter of almost 1 cm. This fistula was excised with a quadruple ligation of the vessels. They appeared to be muscular branches from the peroneal vessels.

Following excision of these four aneurysms the patient recovered uneventfully. He no longer had any edema and he was able to walk without discomfort. There was no significant

difference in the circumference of the two lower extremities. Both feet remained warm, although on actual measurement with a thermocouple the toes of the right foot tended to be somewhat warmer than those of the left. In a room at 23° C. the temperature of the right toes varied from 32 to 33 and those of the left from 28 to 30. Both dorsal pedal and the right posterior tibial pulses were normal, while the left posterior tibial pulse was absent. Oscillometry at the ankles was 4.5 at 90 mm. on the right side and 3.5 at 90 mm. on the left. The patient had recovered fairly normal power of extension of the right foot and had regained function of all the toe extensors save for the great toe. On walking at a fairly brisk pace for over a mile he experienced no undue fatigue in either leg. His pulse was 72 and blood pressure 108/72. There had been no reduction in cardiac size. The predicted frontal cardiac area for a man of his height and weight was 124 sq. cm. Actual measurement was 112 sq. cm. on admission and remained precisely the same on three subsequent x-ray examinations. An electrocardiogram done before the operations showed no diagnostic deformity. Since the peroneal paresis had so nearly disappeared, a neurosurgical consultant agreed that no operative procedure was indicated. The patient was returned to duty.

DISCUSSION

A case is presented which illustrates the great care which is necessary in order to avoid overlooking the presence of arteriovenous aneurysms, particularly if they are relatively small and multiple. This patient had four arteriovenous communications, the first of which was not recognized until two and one-half months after injury and the last of which was discovered only on the operating table after excision of the third. Not only should careful auscultation and palpation be an essential part of the examination of every wounded patient, but palpation for thrill and auscultation for bruit should invariably be carried out during the final stages of any operative procedure performed for the cure of arteriovenous aneurysm.

It is of interest that of the four arteriovenous aneurysms present in the patient reported, two were associated with small saccular aneurysms and a third was a double fistula in which the artery communicated directly with two companion veins.

CONCLUSION

A case is reported in which four distinct arteriovenous aneurysms occurred in a single individual. The importance of careful examination preoperatively and at the close of operation in the recognition of arteriovenous aneurysms is discussed.

SKIN TRANSPOSITION IN INCISIONAL DEFECTS

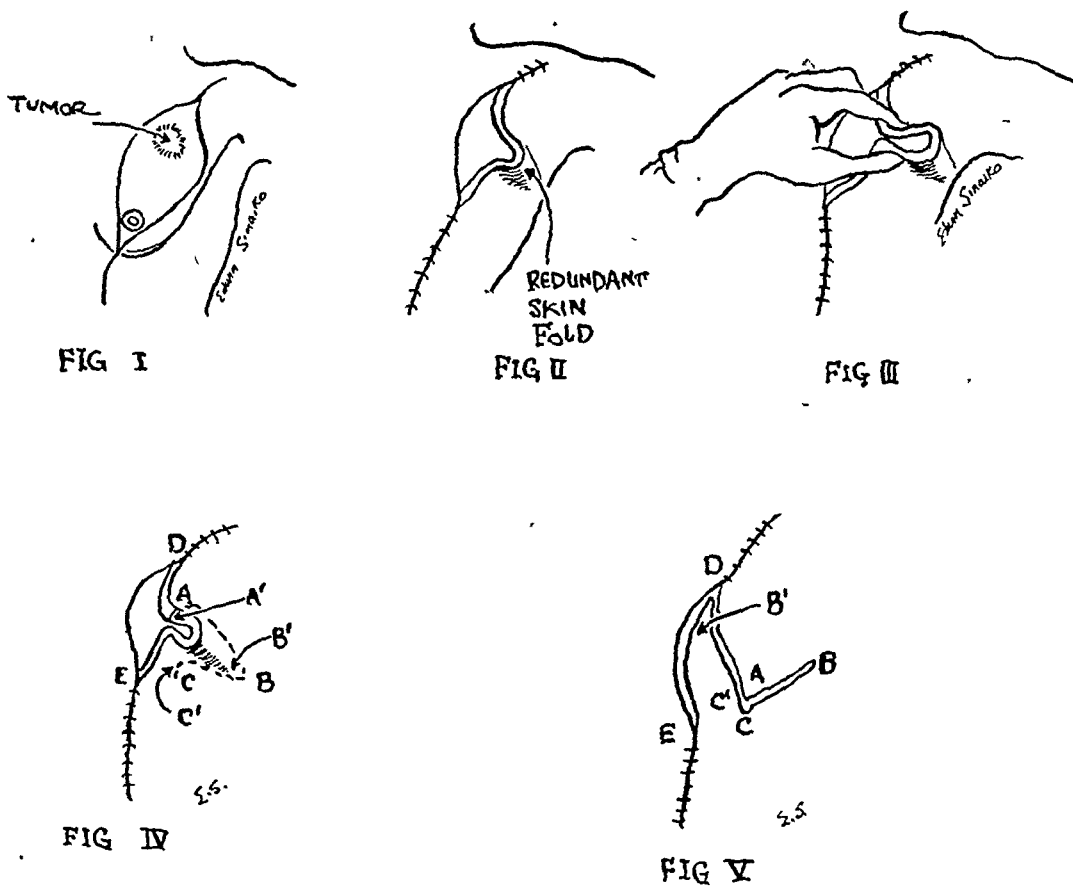
A MODIFICATION OF THE Z PLASTIC FOR PRIMARY SKIN CLOSURE FOLLOWING EXTENSIVE BREAST SURGERY

EDWIN S. SINAICO, M.D., CHICAGO, ILL.

FREQUENTLY the radical surgery of breast carcinoma requires the sacrifice of large areas of skin. When closure of the incision is attempted in these patients, the surgeon may find that he cannot bring the skin edges together and a large defect is left. This defect, although it may be in any part of the incision, is usually seen in the center. The three methods ordinarily used to cover this gap with epithelium are (1) by granulation and eventual epithelization across the defect from the bordering skin edges, (2) by skin grafting either

immediately or after granulation has proved that spontaneous epithelization cannot occur, and (3) by the transposition of skin flaps. The standard textbooks in surgery describe fully the different methods of skin grafting and the usual methods of mobilizing and transposing skin flaps into such a defect.

I wish to report a method of skin transposition used to close extensive skin defects. This method is a modification of the Z plastic which appears in the literature and in texts on the subject; it is one which has been found very useful. Because of the almost constant presence of skin redundancy in the region of the anterior axillary line, this operation lends itself especially to breast surgery. However, it will be found useful in any situation where there is an excess of skin along the border of the incision which must be transposed before it can be utilized.



Figs. I to V.

Following a mastectomy on the service of Dr. Max Cutler, where the patient required a wide removal of the skin overlying the tumor, it was impossible to close the skin wound in the region of the defect. This difficulty was increased because the tumor was in the upper central segment of the breast in a position where under optimum conditions there is practically no excess of skin (Fig. I). If the medial and lateral flaps were undermined, the upper and lower angles of the incision could be closed, leaving a central defect (Fig. II). This skin laxness could be taken up in a fold at right angles to the long axis of the incision is quite a constant finding and a dependable source of skin for flap transposition (Fig. III). Judgment as to how much skin could be utilized was obtained by pinching the fold between the thumb and forefinger. All of the utilizable

skin then lay between the thumb and forefinger. The thumb and forefinger, since they were able to bring together the moderately taut skin above and below the proposed flap, also outlined the skin borders of the flap to be closed after flap transposition.



Fig. VI.—Appearance of the operative incision six weeks after surgery.

An incision was then made mobilizing the flap (Fig. IV), extending along the broken line from *A* to *B* to *C*, *C* to *E* being the pedicle of the flap. *A'* to *B'* to *C'* to *E* now outlined the limits of the skin flap itself. *B'*, the apex of the mobilized flap, was then carried to angle *D* (the upper angle of the defect) and sutured into position. Point *A* was then carried to point *C* and sutured. The transposition having been effected, appropriate sutures were placed which completed the operation (Fig. V). Fig. VI, a photograph of the patient described, shows the result of the plastic procedure six weeks after the surgery.

THE USE OF COTTON SUTURES IN LOWER ABDOMINAL SURGERY

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THE successful use of cotton thread as suture material depends on the close adherence to the principles laid down by Halstead¹ for silk. This is a very exact technique, and strict attention must be paid to place the suture carefully in order to avoid any added trauma by needless strangulation of the tissues of the wound. Cotton is an excellent suture for nontraumatic surgery, since being weaker than silk, linen, or catgut, it breaks more readily when too much pressure is applied.

The size of the suture used is of no great importance as long as the tensile strength of the thread is greater than that of the tissue approximated. Interrupted sutures are generally used,²⁻¹¹ although I¹² have had successful results sewing the layers of the abdomen with continuous threads. Nevertheless, cotton does promote a foreign body reaction, and therefore, the least possible amount of this thread should be used.

Sometimes, in order to avoid using much of this nonabsorbable material, the surgeon is negligent in tying off the small blood vessels, which very often results in the formation of a hematoma that spreads the wound open and delays healing. Careful hemostasis is essential and, in my opinion, is the most important single factor in the technique of using cotton sutures. There must be accurate reapposition of the divided structures without tension. A layer of the wound that requires a heavy suture to bring it together was not meant to be united. As Thorek and associates¹⁰ said, "All that can be expected of a suture is that it will keep the tissues approximated. The process of healing is a natural phenomenon and occurs in spite of the suture used."

Ginkovskiy,¹³ after experimenting on 100 animals and 23 human beings, advocated the use of cotton in surgical procedures on man in 1936. Following the report of Meade and Ochsner,² in 1939, the use of cotton as suture material has become widely applied. These authors reported that, of 196 different major operations, 191 wounds healed by primary intention. There were 3 serious and 2 minor infections, all of which healed without sinus formation. No. 30 plain cotton or "heavy duty" mercerized was used for the approximation of the peritoneum and fascia; No. 10 crochet cotton was used for retention and through-and-through sutures; No. 60 for ligation of small blood vessels and subcutaneous fat, and No. 50 black thread for the skin closure since it can be seen more easily than bloodstained white thread.

Localio and Hinton,⁵ at the New York Post-Graduate Hospital, used cotton thread in more than 50 major operations and found it to be satisfactory and economical. Cotton sutures have been used routinely at the Charity Hospital of New Orleans for eighteen months in over 1,600 cases.⁶ A study of 465 consecutive wounds in which cotton was used demonstrated it to be highly satisfactory. Thorek⁷ followed Taylor⁴ in using only one-sized cotton thread, No. 24, for every type of suture from peritoneum to skin closure.

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Nelson and Collins⁸ reported on 160 gynecologic and obstetric cases in which cotton suture was used exclusively. The heaviest suture used was No. 40 in total hysterectomy, while No. 80 and 120 were used throughout in pelvic and plastic repairs. These authors pointed out that the successful use of these sutures depends on the adherence to the principles of Halstead,¹ which include such an exactness of technique that the operating time is slightly increased. In 115 cases with abdominal incisions there were no serious wound infections, and the incidence of slight infections was only 8.5 per cent as compared to approximately 20 per cent in similar cases during the preceding years. Although the patients were all ambulatory twenty-four to forty-eight hours after operation, there were no wound disruptions. The great degree of comfort was due, in my opinion, to the lack of tissue reaction to the suture material.

Pannet,¹⁴ in making a plea for the wartime use of cotton sutures, discussed his method of suturing a laparotomy wound with removable continuous sutures. The peritoneum and posterior and anterior rectus sheaths are sutured separately with cotton threads, the ends of which are brought out of the skin and tied around a piece of rubber tubing. In eight to ten days, the ends are cut and the thread is drawn out of the wound. Hanly¹⁵ obtained excellent results by substituting cotton and linen sutures for catgut in herniorrhaphies, and by the liberal use of sulfanilamide powder in the wound.

An interesting report is that of Sparkman and Williams⁹ who, in a tent, performed 124 consecutive appendectomies on soldiers engaged in field maneuvers simulating warfare. No. 20 or 8 cotton was used for ligating the mesoappendix. The peritoneum and the layers of the McBurney incision were closed with interrupted No. 50 or 80 cotton thread; No. 100 white thread was used for ligating the blood vessels beneath the skin, and No. 80 black thread for skin closure. There were 79 appendectomies with histopathologic evidence of acute suppuration; 27 of these were gangrenous. There were 2 cases of perforation and 2 cases of contamination; these 4 were drained. Of the 120 clean cases, the incidence of wound infection was only 0.83 per cent. These results seem to justify the conclusion that cotton thread is satisfactory for field use in clean, contaminated, or infected wounds.

Thorek and co-workers¹⁰ used cotton thread in over 400 cases, including patients with perforated appendices and diabetic gangrene, with an incidence of infection of less than 4 per cent. They reported no draining sinuses, although cotton was intentionally used in infected wounds. In their last 20 leg amputations, there were only 2 infected wounds, and in both cases catgut and silk were used.

Word and Brock¹¹ reported over 200 cases from Camp Shelby, in which cotton suture was used. In 22 contaminated wounds, 19 healed by primary union, with 3 wound infections and 1 draining sinus; in 198 clean cases, 195 healed by primary union with 3 infections and 2 draining sinuses. These authors stated that the success of cotton suture depends upon the strict attention to the fundamental surgical principles. They claim an increased operative time of 15 to 20 per cent and, therefore, do not advocate cotton as a good wartime suture.

Meade and Ochsner² found cotton thread to be an extremely satisfactory suture as it is easily sterilized, flexible, and produces little tissue reaction. Sterilization is accomplished by boiling for twenty minutes or by autoclaving for fifteen minutes at fifteen pounds pressure with the cotton wound on a rubber spool or a spool which does not expand in water, as the cotton shrinks and the fibers may be broken.

Thorek⁷ said that cotton may be buried in infected wounds without inducing sinus formation, as occasionally happens when silk sutures are used. He has shown that there is no infiltration of leucocytes into cotton and consequently no formation of granulation tissue, since cotton fibers have a natural tendency to twist upon themselves, and not fray as silk or linen. This may explain the absence of draining sinuses in cotton-sutured wounds, since it is believed² that the infected granulations imbedded in the silk give rise to these sinuses, which are not cured until the silk thread is removed.

Wounds sewn with cotton result in rapid healing without any serum accumulation. This is termed "dry" healing by Thorek,⁷ since cotton sutures produce a minimal amount of exudate, and fibroblastic proliferation appears early. The use of catgut produces "wet" healing associated with an excessive fluid exudate and delayed fibroblastic appearance. This lack of wound irritation enables the patient to have a smoother postoperative convalescence with very little wound discomfort and earlier healing. None of the reports notes the development of foreign body tumors or unusual keloid formation.

Dry cotton has less tensile strength, size for size, than catgut, silk, or linen, but it shows less decrease in tensile strength (break strength) than the others. After sutures were imbedded in tissue for ten days, cotton maintained its tensile strength at 100 per cent, whereas silk, linen, and catgut had a tensile strength loss of 25, 40, and 70 per cent, respectively.¹⁶ For this reason the patients may be made ambulatory much sooner than in other types of abdominal closure.

The cotton chosen for suture should be limited to the smallest diameter that has greater tensile strength than the tissue in which it is used.¹⁷ Wet cotton has greater initial strength than dry cotton, and many surgeons prefer to sterilize the thread by boiling rather than by autoclaving, since cotton has been shown⁵ to diminish in tensile strength after autoclaving and to increase after boiling. However, this decrease can be abolished by rewetting the cotton before use. Mercerized cotton is much stronger than plain cotton and may be used to coaptate tissues under tension. All sutures, although cotton has a high coefficient of friction and is not likely to slip after the first throw of a square knot, should be tied with a triple throw knot and then cut on the knot.¹⁸

At the Manatí Municipal Hospital an experiment was begun in December, 1942, using buried continuous cotton sutures in all the layers of the abdominal wall except in hernia repair, where interrupted sutures were used. This method of suturing was first used in small midline incisions for post-partum sterilizations, and since the results were excellent, the same technique was applied to other types of abdominal closure. One hundred fifty-one lower abdominal operations were done: 87 midline incisions divided into 43 laparotomy and 44 post-partum (the latter incision is only two inches long as compared with the usual midline wound of four to six inches), 10 McBurney, 38 right rectus, and 16 inguinal. Two of the midline incisions were for cesarean section; the uteri were closed with catgut, but the peritoneum and layers of the abdominal wall were sutured with cotton.

There was 1 postoperative hernia following a post-partum midline incision. This woman had a remarkably relaxed abdominal wall with diastasis recti at the time of operation. Subsequently, she not only developed an incisional hernia, but a separation of the fascia in the midline from above the umbilicus to the symphysis pubis. This extensive ventral hernia was repaired successfully ten months later using only interrupted cotton sutures in the fascia, after closing the peritoneum with a continuous suture. At this time we obtained a sample of tissue (Fig. 1). There was dense fibrosis in the operative field and no vestige

postoperative day despite local implantation of sulfathiazole and the taking of sulfathiazole by mouth. Healing took place in four months, only after all the cotton thread had been expelled.

In nine post-partum incisions done under 1 per cent novocain-suprarenin local anesthesia, the formation of hematomas delayed wound healing by spreading the subcutaneous tissues. Three wounds were brought together with secondary sutures, and the rest healed well by approximating the skin edges with flamed adhesive.

With the exception of the two cesarean sections which showed several small stitch abscesses, all the midline incisions healed without any infection. Two of the inguinal wounds had some drainage from small subcutaneous hematomas and slight infection of the skin edges. (The inguinal operations were all done under local anesthesia, 1 per cent novocain-suprarenin solution.) After the sutures were removed on the eighth postoperative day, both wounds healed well without any discomfort to the patient. With the exception of the herniorrhaphies the patients were allowed to sit up on the second day, but were not allowed to walk until the sutures were removed from the skin, usually by the eighth day.

After experimenting with all sizes of cotton thread mentioned in the literature, we found that one-sized cotton, No. 50, gave the best results. Where a stronger suture was needed, such as for ligating the base of the appendix, this size was doubled. Since the thread is autoclaved with the instruments and used dry, it breaks very easily if too much strength is applied to tie the first few knots, but as the thread becomes wet with the secretions of the wound, it becomes stronger. Also, it is unwise to autoclave cotton thread more than one time, if it is to be used dry, since with each sterilization the cotton becomes weaker and breaks more readily. The cost of this type of suture is so small that all unused packets are sent to the emergency room and not used in the operating room again. The cost of suturing an abdominal wound with cotton is less than 2 cents, as compared with \$1.50 for catgut.

The operative technique follows that of catgut with the exception that a triple-throw square knot is used, and the suture is cut on the knot. All pelvic work and peritonealization is done with continuous sutures. The larger vessels are ligated with No. 50 thread, and unless there are any active bleeders in the subcutaneous tissues, no vessels are tied; also, the subcutaneous layer is not sutured. The superficial bleeding is usually controlled by the interrupted deep mattress sutures in closing the skin. No through-and-through sutures are used, but Taylor stated⁴ that if they are used, they act as subfascial as well as subcutaneous drains, which may explain the absence of serum accumulation in the wounds of his cases. At least 5 Gm. of sulfonamide powder are sprinkled in the abdomen and layers of each wound. The skin sutures are usually removed on the seventh or eighth postoperative day.

TABLE I. SUMMARY OF CASES

	NO.	PRIMARY UNION	WOUND INFECTION	REMARKS
Clean cases	143	130	2	2 incisional hernias, 11 hematomas
Contaminated cases	8	7	5	1 sinus
Total	151	137	7	

COMMENT

From the experience in this group of cases the following principles concerning the use of cotton thread sutures may be stated.

1. Single unit, No. 50, cotton thread is used throughout the wound.

2. Continuous suture is permitted in the peritoneum as well as the fascial layers of the lower abdominal wall.

3. Transfixion sutures and figure-of-eight fascial and mattress retention sutures are not necessary.

4. The closure of the subcutaneous fatty layer is not necessary.

SUMMARY

1. Continuous cotton thread sutures have been used successfully in the peritoneal and fascial closure of lower abdominal wounds, thus speeding up the time of operative technique to equal that of catgut.

2. Single unit, No. 50, cotton thread is recommended; where stronger suture is needed, this thread is doubled.

3. Two cases of incisional hernia are reported. Nine cases of hematoma formation in post-partum midline incisions done under 1 per cent novocain-suprarenin local anesthesia were noted, emphasizing the need for meticulous hemostasis. In none of these cases did the wound disruption extend below the subcutaneous fatty layer, although one wound discharged the hematoma ten days postoperatively after the patient had been sent home.

4. The advantages of cotton thread are: low cost, easy availability; stability on exposure to heat and moisture, and ease of sterilization; a high coefficient of friction allowing the tying of secure knots, and, last, it does not irritate the wound, since it produces no tissue reaction, thus affording greater comfort to the patient.

5. The only disadvantage to the use of cotton is its lower initial tensile strength as compared with catgut, silk, or linen, but this is offset by the greater retention of tensile strength in the tissues.

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Book Reviews

Hypertension and Hypertensive Disease. By William Goldring, M.D. and Herbert Chasis, M.D., New York University College of Medicine. Ed. 1. Pp. 232. New York, 1944, Commonwealth Fund. \$3.50.

In this book the authors accomplish what they clearly state in the preface to be their objective, "a concise presentation of our concepts of hypertension and hypertensive disease." The renal functional studies of Dr. Homer W. Smith and the clinical applications of these techniques to the hypertensive patient are well described. The sections of the book devoted to this subject and the appendices dealing with the techniques of the various procedures are in themselves extremely worth while. In addition the chapters on medical and surgical treatment, and the management of hypertension are especially to be recommended.

The 1944 Year Book of General Surgery. Edited by Evarts A. Graham, A.B., M.D., Professor of Surgery, Washington University School of Medicine, St. Louis. Pp. 736, with 271 illustrations. Chicago, 1944, The Year Book Publishers, Inc. \$3.00.

This book presents a number of new operative techniques and new devices useful to the surgeon in the performance of operations or management of patients. In the main, however, the volume contains, as its editor states, very little which is strictly new. The volume contains sections on anesthesia, antisepsis, operative technique, military surgery, wound healing, tumors, and surgery in its regional anatomic aspects.

The book has come to be an important current source book for the surgeon. Many a surgeon who essays to keep abreast of developments in fields of surgery, somewhat unrelated to his own, will find in thumbing through the pages of this book, items of real interest which had not come to his notice. Moreover, most surgeons will find in it some items in their own particular field of interest which had escaped their attention on first publication.

The Year Book fulfills a useful function and should be read widely by all who profess an interest in improving their orientation in the broad field of general surgery.

Announcement

Due to conditions beyond the control of the editors and publishers, several issues of the JOURNAL are printed on an inferior grade of paper. Just as soon as the standard good grade of paper is available, its use will be resumed.

SURGERY

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Original Communications

SURGICAL TREATMENT OF LONG-STANDING DEEP PHLEBITIS OF THE LEG

II. A SUPPLEMENTARY REPORT

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SOMEWHAT more than one year ago, we* published the results of our treatment in a small group of patients who had long-standing deep phlebitis of one or both of the lower extremities. The patients considered in this series had had a deep phlebitis with onset from two months to thirty years before their admission to the University Hospital. All of the patients of this series, treated by femoral vein ligation, came to us because of pain or disability resulting from the chronic deep thrombophlebitis. Femoral vein ligation is no longer novel or unusual but its utilization in this group and number of patients for the indications described is unique. We wish to report here further concerning the results in these patients so treated up to the present time.

This group of patients now numbers twenty-four. They range in age from 14 to 69 years. We have postulated that no patient with advanced arterial disease should be treated in this manner but this standard has been difficult to maintain, particularly in the evaluation of peripheral arteriosclerosis. We have, therefore, arbitrarily set the age limit for this treatment at 55 years. Four of our patients were beyond this limit; their ages at the time of ligation were 57, 58, 64, and 69 years. There were ten women and fourteen men in this group.

The largest number of these patients presented themselves to us because of chronic, recurring ulceration about the ankle. A smaller number desired treatment because of swelling, pain, or great ease of fatigue. Whenever superficial varices were present these were treated by ligation before the decision to ligate the femoral vein was made. Since we have ceased to use the injection method of treatment of varicose veins, none of these patients received injections of sclerosing agents before, during, or after femoral ligation. Likewise, no patient has received lumbar sympathetic blocks before, during, or after femoral vein ligation. The results reported in this group have, therefore, been modified in no way by lumbar sympathetic nerve injection.

In a discussion and tabulation of the results up to the present time in this small group of patients, three of the patients should be specifically mentioned. The first of these is now dead, perhaps as a result of the form of treatment used. This patient was 57 years of age. He had had bilateral varicose veins

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*Buxton, R. W., Farris, J. M., Moyer, C. A., and Coller, F. A.: Surgical Treatment of Long-standing Deep Phlebitis of the Leg. A Preliminary Report. *SURGERY* 15: 749-756, 1944.

for ten years. An ulcer appeared on the left ankle two years before his admission to the University Hospital and this had failed to heal despite various forms of therapy. At the time of his admission it was noted that his vascular age was considerably greater than his chronologic age; there was considerable atrophy of the skin of the lower extremities, hair was absent on the legs, and the peripheral pulses, the dorsalis pedis and posterior tibial, were absent bilaterally. At this patient's second admission, three months following the first, the examining physician emphasized the degree of cerebral arteriosclerosis present. The patient had multiple ligations of superficial varices without effect upon the supramalleolar ulcer. On Nov. 23, 1943, the left superficial femoral vein was ligated. The patient tolerated the procedure well and was discharged after removal of the skin sutures. He returned to the outpatient department Jan. 18, 1944, with the original supramalleolar ulcer completely healed. However, the site at which a cut-down had been carried out for obtaining venographic studies was infected and ulcerated. This cleared slowly with rest, elevation, and sterile dressings. On Feb. 26, 1944, two superficial varices were discovered near this area of ulceration and ligation under local procaine anesthesia. On Feb. 28, 1944, the patient's temperature was 104° F., and there was a diffuse cellulitis of the left leg. A diagnosis of surgical erysipelas was made. A regime of complete bed rest, elevation of the leg, moist compresses, and sulfadiazine was begun. There was eventual extensive sloughing of skin and subcutaneous tissues with the infection extending into deep muscle and fascial planes. Cultures from the area showed *Staphylococcus aureus*, *Streptococcus viridans*, and *Micrococcus tetragena*. Despite a varying course the patient gradually deteriorated. Because of a septic arthritis of the left ankle a guillotine amputation was done May 26, 1944. The pathologic specimen showed organized thrombi in the arteries. The patient finally became confused and then comatose. Death occurred on June 4, 1944. All blood cultures taken during the patient's illness were negative.

Had we evaluated this patient's condition correctly, ligation of the femoral vein would not have been done; not only was he above the accepted upper age limit but physiologically he was much older. It is impossible to decide whether ligation of the femoral vein, distal to the profunda femoris branch, had any adverse effect upon the infection which this patient developed three months later as a result of the minor surgical procedure carried out. However, certainly the underlying arterial disease did contribute greatly to the course of the disease. No necropsy was obtainable upon this patient so that a final answer to many of our questions is not forthcoming.

The second patient in this group was reported in our previous publication. This patient required incision and drainage of a residual abdominal abscess four months following femoral vein ligation. Forty-eight hours after incision and drainage, symptoms of an acute arterial embolism appeared in the popliteal artery and subsequent amputation was necessary. The leg had been asymptomatic in the four-month interval and we are of the opinion that the femoral vein ligation was in no way related to the subsequent difficulty. At the time of amputation, the operator noted that both artery and vein were occluded by thrombi. The venous thrombi were well organized.

The third patient deserving special attention was also reported in the previous paper. This patient developed increasing bilateral leg edema associated with enlarging dilated thoracoabdominal veins over a period of two months following left femoral vein ligation. Ligation of the inferior vena cava just above the common iliac veins was done. This patient has made a satis-

factory convalescence, is edema free, and all leg ulcers have healed and remained healed for more than one year. He is asymptomatic and is considered cured, a result brought about by vein ligation. However, the satisfactory outcome must be attributed to the vena cava ligation rather than to the ligated femoral vein.

There still remain twenty-one patients for consideration (Table I). The femoral vein has been ligated on both sides in two of these patients, making a total of twenty-three ligations in twenty-one patients. The left femoral vein was ligated seventeen times, the right, six times (two patients had bilateral vein ligations). The common femoral vein was ligated ten times, the superficial femoral vein (femoral vein beyond the profunda femoris branch), thirteen

TABLE I

NUMBER	AGE	DURATION OF SYMPTOMS	DATE OF VEIN LIGATION	SIDE	LEVEL OF LIGATION	SIZE OF ULCER PRE-OPERATIVE (CM.)	PRESENT STATUS OF ULCER	EDEMA OF LEG	EXTERNAL SUPPORTS	LIGATION VARICES	VARICES NOW	EASE OF FATIGUE
532,514	30	4 yr.	9/11/43	Right	C*	2 × 2	Healed 1 yr.	+	+	+	0	0
526,215	26	10 yr.	9/22/43	Left	S†	4 × 4	Healed 1 mo.	0	+	+	0	0
331,424	44	14 yr.	10/19/43	Left	C	3 × 4	Healed 1 yr.	0	+	+	0	0
534,858	29	7 yr.	10/14/43	Left	C	3 × 3	Grafted, healed	+	+	+	+	+
451,929	43	4 yr.	10/20/43	Left	S	None		++	0	0	+	0
		3½ yr.	10/20/43	Right	S	None		++	0	0	+	0
282,432	69	32 yr.	11/ 2/43	Left	S	2 × 2	Healed 1 yr.	0	0	0	0	0
536,332	53	2 mo.	11/ 5/43	Left	C	None		0	0	0	0	0
533,703	27	3 yr.	11/ 9/43	Left	S	Surr. entire ankle	Healed 1 year	0	0	0	0	0
534,932	57	10 yr.	11/19/43	Left	S	3 × 2½	Healed	Death 6/4/44 fol. severe leg infection post ligation varices. Ligation Inf. Vena Cava 1/26/44				
535,940	58	3 mo.	11/23/43	Left	C	None						
535,678	47	4½ yr.	11/24/43	Right	C	None						
464,686	55	10 yr.	12/ 4/43	Left	C	3 × 4	Healed 1 yr.	+++	0	0	0	+
525,436	30	5 yr.	12/ 6/43	Left	S	2½ × 1½	Not healed	+	0	+	0	0
519,228	33	2 yr.	12/ 8/43	Left	S	None		+++	0	0	0	+
534,810	43	2 yr.	12/31/43	Left	S	2 × 1	Healed 4 mo.	+	+	+	0	+
			5/15/44	Right	S	2 × 2	Healed 4 mo.	+	+	0	0	0
519,177	14	6 yr.	1/ 8/44	Left	S	1 × 3	Healed 1 mo.	0	0	0	0	0
219,340	54	10 yr.	1/11/44	Left	C	None		+	0	0	0	+
506,492	64	3 mo.	1/13/44	Right	S	None		++	0	0	0	+
482,504	32	4 yr.	1/13/44	Right	S	2 × 3	Not healed	+	+	0	?	+
301,423	52	2 yr.	1/21/44	Left	S	1 × 1	Healed 1 yr.	+	0	0	+	+
545,940	37	15 yr.	6/23/44	Left	C	3.5 × 5	Healed 3 mo.	0	0	0	0	0 (6 mo. pregnant)
552,762	47	4 yr.	8/18/44	Left	C	5 × 2	Healed	0	0	0	0	0
557,450	54	2 yr.	10/24/44	Left	C	5 × 5	Grafted, healed	0	+	0	0	0
380,434	41	7 yr.	7/ 2/43	Right	C	5 × 4		11/6/43 arterial embolus 11/22/43 amputation				
						None						

*C. Common femoral vein.

†S. Superficial femoral vein.

times. Fourteen of these patients had chronic ulcerations about the ankle at the time of femoral ligation; one of these had a bilateral ligation with ulcers present on both ankles, thus making a total of fifteen ulcers so treated.

Of the fourteen patients with ulceration, six have now had complete healing of the ulcers for one year or longer; the one patient with bilateral ulceration and bilateral ligation has had complete healing of both ulcers for four months. The ulcers of three patients have been healed for three months or less; another patient's ulcer has been healed for some time, but the exact length of time is not known. In two patients only is the area of chronic ulceration unhealed at the present time. Upon two patients, excision of the ulcer and grafting has been necessary. Upon the first patient a full-thickness graft was placed, an excellent take obtained, and the graft remained satisfactory for about six months. Partial regrafting was done elsewhere and to date this has remained satisfactory. The patient reports visibly distended varicose veins but has failed to return for treatment of these. Upon the second patient Reverdin grafts were placed on two large ulcers. The grafts have remained on one ulcer to date (four months) and are satisfactory. A portion of those on the second were lost and have recently been replaced.

In five patients ligation of superficial varices became necessary following femoral vein ligation. There is a varying degree of rise in the venous pressure of the left following femoral ligation. It is possible that valves formerly competent are no longer so with this rise in pressure; more likely vessels with already incompetent valves become more prominent, elongated, and tortuous with the resulting rise in intravascular pressure. It has been necessary to watch carefully for the appearance of these varices since they have been responsible for the failure to heal of several ulcers and, where healing has occurred, re-appearance of the ulcer has coincided with the appearance of varices. One patient whose ulcer has failed to heal to date was discharged against advice from the hospital and has failed to return since that time. She reports no varices but very probably these are present and failure to heal may well be due to their presence. The second patient with an unhealed ulcer has also failed to return for examination.

Seven of the twenty-one patients did not have ulcerations about the leg or ankle at the time of femoral vein ligation. These seven patients were admitted for treatment because of swelling, pain, and marked ease of fatigue. Reports from all but one of these patients up to the present time indicate that there has been little improvement in the degree of swelling as compared with their preoperative status, and, in addition, ease of fatigue with exercise continues to be a prominent symptom. In none of this group have ulcerations appeared and only one patient shows evidence of superficial varices. These she has refused to have ligated up to the present time. Only one patient in this group is completely asymptomatic.

In this group of seven patients, without ulceration at the time of femoral vein ligation, there has been little improvement from this form of treatment. Theoretically the patients in this group should respond well, perhaps better than those patients with ulceration, since the local and regional soft tissue, vascular, and perivascular reactions to chronic infection are absent. There has been a variable relief of pain, characterized as aching, which may be the result of some release of vasospasm.

The level of femoral vessel chosen for ligation has been based upon the presenting signs and symptoms, pain or swelling extending above the level of

the knee, or the historical evidence of the extent of the original thrombophlebitic process as obtained from the patient at the time of admission. In those patients in whom there was evidence of involvement of the femoroiliac system above the level of the profunda femoris vein, ligation of the common femoral vein was carried out. In the remainder, ligation of the superficial femoral vein was done. The degree and extent of postoperative residual edema are equally distributed between those patients with ligation above and below the profunda femoris branch. Likewise, the number of superficial varices appearing after femoral ligation also seems to bear no relation to the level of ligation since they are equally distributed in the two groups of patients. In so far as we are able to judge, the level of vein ligation, above or below the profunda femoris branch bears little relation to the degree or duration of postoperative edema, to the appearance of superficial varices postoperatively, or to the end result.

ILIAC VESSEL LIGATION

We have had occasion to ligate the common iliac vein in only one patient where a long-standing phlebitis was present. This patient had had a post-abortal femoroiliac thrombophlebitis thirteen years previously with exacerbations at intervals, particularly during subsequent pregnancies. No ulcerations were present at the time of her admission to the University Hospital. However, there had been a mild flare-up of the phlebitic process recently and one day pre-admission, the patient had a sudden onset of severe chest pain. Hemoptysis did not occur until after admission to the hospital. The patient's subsequent course and response to therapy was such as to lead to a clinical diagnosis of pulmonary infarction. The left common iliac vein was ligated, extraperitoneally, on Sept. 8, 1944. No clot was present within the vein. The vein was ligated in continuity. The patient's course postoperatively was good and there was marked subsidence of the left leg edema at discharge.

This patient was readmitted Dec. 12, 1944, because of continued edema of the left leg. A course of five daily lumbar sympathetic procaine injections was given. With each injection there was dryness and increased warmth of the foot and leg. The patient was kept at complete bed rest for the five days and all measurements of the leg on discharge were the same as on admission. There was slight lessening of the induration in the supramalleolar areas.

Vein ligation was done in this patient primarily for a probable phlebothrombosis superimposed upon a chronic thrombophlebitis. There was little improvement over the preoperative state of the leg in the three months immediately following operation. Postoperative lumbar procaine injection produced little change in the condition of this patient's leg.

VENA CAVA LIGATION

The inferior vena cava has been ligated upon seven patients with a long-standing phlebitis of both lower extremities (Table II). Three of these patients had long-standing stasic ulcers about the ankles. The remainder complained only of pain, swelling, and ease of fatigue. The first patient upon whom this procedure was carried out had had ligation of the common femoral vein two months previously. There was progression of the thigh edema as well as marked progressive dilatation of the thoracoabdominal veins. The second patient so treated had primary healing of the supramalleolar ulcer with subsequent breakdown. She has been recently treated by excision of the ulcer with grafting.

In all of the patients with preoperative ulcers there has been healing during the ten-day postoperative period following caval ligation.

It is to be noted that all of the patients, with the exception of one with a recent ligation, have had a variable degree of postoperative edema. This has been less than that which occasionally occurs following ligation of the femoral vein, particularly for phlebothrombosis. The first patient upon whom ligation of the vena cava was done has now passed the twelve-month period following ligation and has no edema, although prolonged trial without external supports has not been tried. No edema is present when the elastic hose are not worn for short periods. He is able to carry on his occupation as a farmer without pain or fatigue. All of the remainder of the patients in this group are still wearing supports constantly and by this means are able to control the edema well. Fatigue, in each of these with edema, is still present to some degree.

TABLE II

NUMBER	AGE	DURATION OF SYMPTOMS	DATE OF VEIN LIGATION	SIDE	LEVEL	SIZE OF ULCER PREOPERATIVELY	PRESENT STATUS OF ULCER	EDEMA OF LEG (s)	EXTERNAL SUPPORTS	LIGATION OF VARICES	VARICES NOW	EASE OF FATIGUE
<i>Iliac Vein Ligation</i>												
554,108	37	13 yr.	9/ 8/44	Left	Common iliac	None		+	+	0	0	+
<i>Vena Cava Ligation</i>												
535,940	58	6 mo. (r.) 5 mo. (l.)	1/26/44	V.C.	V.C.	None		0	+	+	0	0 (L. fem. vein lig. on 11/23/43)
515,544	48	9 yr. (l.) 1 yr. (r.)	8/24/44	V.C.	V.C.	1x1 cm. None	Grafted	++	+	0	0	+
556,214	32	11 mo.	10/10/44	V.C.	V.C.	2x1 cm. (l.)	Healed	+	+	+	0	+
559,620	56	10 yr. (l.) 6 yr. (r.)	12/19/44	V.C.	V.C.	1x1 cm.	Healed	++	+	0	+	+
562,735	49	1½ yr.	2/ 1/45	V.C.	V.C.	None		++	+	0	0	+
442,296	38	6 mo. (r.) 5 mo. (l.)	2/ 2/45	V.C.	V.C.	None		+	+	0	0	+
560,140	43	11 yr. (l.) 9 mo. (r.)	2/ 3/45	V.C.	V.C.	7x5 cm. None	Healed	0	+	0	0	+

DISCUSSION

It is to be noted that in this group of patients upon whom vein ligation has been tried as a definitive form of therapy in the treatment of their chronic deep thrombophlebitis, the intensity and care with which they have been followed and observed during their postoperative period are much greater than that usually given patients with this disease. This has undoubtedly influenced greatly the end results seen in this small group of individuals. Had this not been done, the good results up to the present time might well have been no different than with the multitude of other forms of treatment outlined in the past for this group of patients. How much the end results are influenced by the operative procedure and how much by the constant postoperative care cannot be stated.

The outstanding end result that can be reported up to the present time is the high incidence of healing of stasic ulcers. In each group of patients, those treated by femoral vein ligation and those by vena caval ligation, there has been

immediate and permanent healing of a certain number of ulcers. There is a second group of patients in whom healing has been long delayed, or in whom healing has occurred with subsequent reulceration and subsequent healing only after ligation of newly present superficial varices. In one individual (No. 526,215) this has occurred four times, healing occurring promptly after ligation of the newly discovered varices. Thus, each of these patients must be watched carefully over a period of at least one year's time for appearance of varices in the superficial venous system. Despite the fact that the appearance of these suggests that they are a portion of the developing collateral venous system, ligation is imperative since their persistence presages a recurrence or reappearance of stasic dermatitis and ulceration.

The most disappointing patients have been those upon whom ligation has been done in the absence of stasic ulceration. A large number of this class of patients will eventually develop induration, pigmentation, and ulceration, perhaps many years later. In these individuals venous ligation was considered an attempt not only at therapy but at prophylaxis. From the standpoint of therapy, the treatment may be considered a failure. Dependent edema and ease of fatigue appear to be little relieved while pain is still present though unpredictably diminished in some. It remains to be seen whether subsequent ulceration has been prevented in these patients.

A comparison between those patients treated by femoral vein ligation, iliac vein ligation, and caval ligation cannot be made at the present time. The magnitude of the operative procedure is considerably greater the higher in the venous tree ligation is carried. To date no deaths have occurred among those patients subjected to iliac or caval ligation. The immediate end results appear to be the same, although sufficient time has not elapsed to make an accurate comparison. Unfavorable late sequelae to iliac or caval ligation have not been encountered.

VENOUS PRESSURES IN DISORDERS OF THE VENOUS SYSTEM OF THE LOWER EXTREMITIES

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IT SEEMS worth while to report some observations on the venous pressure found in disorders of the venous system of the lower extremities. The direct determination of the venous pressure in the lower extremities is not often made. This is due in part to the fact that the value of the estimation of the venous pressure has not been frequently called to the attention of surgeons and in part to the technical difficulties in performing the task.

TECHNIQUE

There are several methods for determining the venous pressure. The methods used in this work are as follows: The venous pressure is taken in one of the veins of the foot or ankle. In most instances the saphenous vein near the in-

ternal malleolus is the most satisfactory vein to use. The patient is placed in the supine position and the table adjusted so that a base line corresponding to the auricular level of the heart can be measured on the manometer. There are two methods that we use. Either method is satisfactory. The largest caliber needle that can be introduced in the vein is used. The most satisfactory size is No. 19.

In one method the system of tubing is filled with normal saline solution. The three or four inches of tubing to be attached to the needle is then filled with 2½ per cent sodium citrate solution and the glass connector attached to the needle already in the vein. The saline solution in the glass tubing is slightly above the base line of the heart level. Blood is allowed to flow into the cannula and tubing and the maximum elevation of saline solution in the glass tubing is read as the venous pressure.

The second method¹ is similar to the first except that the system is filled with 2½ per cent citrate solution and a three-way stopcock is used to connect the needle and the tubing. The citrate solution in the glass tubing is slightly above the expected venous pressure. The apparatus is then attached to the needle in the vein and the citrate solution allowed to run into the vein. When no further citrate solution runs into the vein the pressure of the column of citrate then equals the venous pressure.

Both of these methods have been described before. Using these methods it is necessary to observe a few precautions to secure accurate results. The needle must be a size No. 21 or larger, otherwise there will not be a free flow of the solution and clotting in the needle may occur. The needle must be introduced into the vein with the minimum of trauma to the vein so that local spasm of the vein is largely avoided. Blood must flow into the needle freely. The venous pressure must be taken in both lower extremities at about the same time for purposes of comparison.

There are many instances in which the determination of the venous pressure in the lower extremities will provide diagnostic or prognostic information. It is known that when the femoral vein is ligated in the hind leg of a dog the venous pressure in this extremity immediately rises.² In this article it is shown that the venous pressure in the lower part of the leg of human beings will rise when the femoral vein of the lower leg is occluded. At what level it is necessary for the veins of the lower extremities to be occluded in order for the venous pressure at the foot to rise is not known, but it is known that when the superficial femoral vein is occluded by a clot of blood the venous pressure at the ankle and foot rises markedly.

A large number of venous pressure determinations have been made. Cases 1, 2, and 3 are cited as examples:

CASE 1.—A right pelvicolithotomy was done on March 19, 1945, for calculus disease. No evidence of phlebothrombosis in either leg was recognized until April 5, 1945, when the patient developed signs and symptoms of a left femoral vein thrombosis. The following day the left superficial femoral vein was opened and a long clot removed. The clot was not adherent to the vein wall and was removed easily. Small clots were removed by suction proximally and the vein divided. The venous pressure just before the phlebotomy was 49 cm. of water pressure. Immediately postoperatively the pressure in the left saphenous vein at the ankle was 60.5 cm. The following day the pressure in the left foot was 47.5 cm. and in the right foot 2 cm.

Therefore, there was a significant and diagnostic elevation of the venous pressure in the left saphenous vein at the ankle when a clot was proved to be present in the left femoral vein.

In thrombosis of the distal vena cava the venous pressure at each ankle will be high until a collateral circulation is developed which will adequately drain the blood from the extremities. Whenever there is a bilateral elevation of the venous pressure in the lower legs the pressure must also be taken in the arms to rule out a general increase in the venous pressure, for example, in congestive heart failure.

An important use of the estimation of the venous pressure occurs in the diagnosis of cases of edema of the lower extremities. If the venous pressure is normal in the lower legs after exercise, as described by Veal and Hussey,³ it is fair to assume that the major venous channels of the lower legs are patent and that the cause of the edema must be found elsewhere.

Venous pressure determinations would appear to be valuable in following cases of venous thrombosis in the lower extremities during convalescence in order, first, to choose the optimal time for the patient to be ambulatory, and second, to regulate his activities.

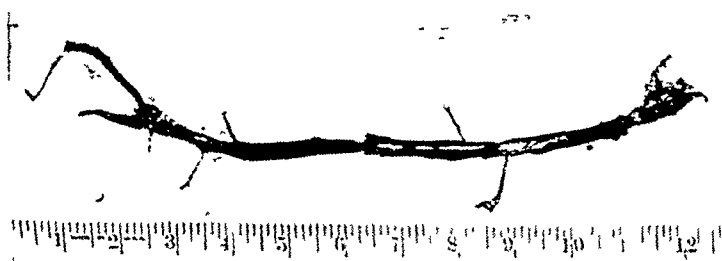


Fig. 1 (Case 1).—Blood clot removed from left femoral vein.

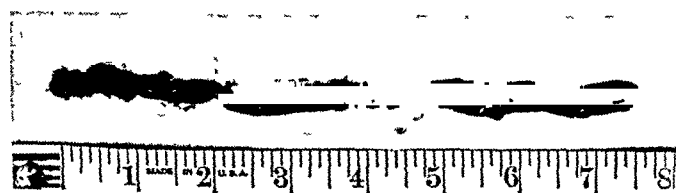


Fig. 2 (Case 2).—Blood clot removed from left femoral vein.

CASE 2.—A left venous thrombosis occurred in the femoral vein fourteen days after a cholecystectomy had been performed. Operation was performed the same day. A long clot was removed from the distal femoral vein, small clots were removed by aspiration from the proximal vein, and the femoral vein was ligated and divided. Two days after the femoral vein operation the venous pressure at the left ankle was $24\frac{1}{2}$ cm. and at the right ankle 3.8 cm. One week later the pressure at the left ankle was $34\frac{1}{2}$ cm., two weeks later 25 cm., three weeks later 21 cm., and four weeks later $19\frac{1}{2}$ cm. At the time of the first venous pressure listed here, there was slight edema of the left lower leg. There was moderate edema at the time of the next venous pressure and the edema progressively decreased from that time forward.

CASE 3.—A left femoral thrombophlebitis occurred ten months before admission, following a shrapnel wound of the left thigh and perineal region. Edema of the left leg persisted during these ten months with a progressive tendency for the edema to improve. Venous pressure at the left ankle was 21 cm., at the right ankle 2 cm. It was, therefore, concluded that the left venous system contained a significant amount of blockage. One month later the venous pressure at the left ankle was 14 cm. and there was little edema with increasing activity. This indicated an improving venous circulation in the extremity.

COMMENT

It has been shown that the venous pressure at the ankle is elevated when the femoral vein has been occluded by a blood clot. Whether or not the venous

pressure at the ankle is increased with a phlebothrombosis in the calf group veins is not known. Likewise, whether or not the pressure is increased in cases in which the thrombosis is in the veins of the foot is not known. It may be assumed that with any appreciable amount of venous thrombosis in the lower leg, the pressure will be increased significantly.

It is frequently a problem to know in which lower extremity the venous thrombus is present or whether the thrombus is present in both lower extremities. It is suggested that venous pressure determinations are useful in determining this point and therefore are of assistance in choosing which femoral vein to expose at operation.

It has been suggested⁴ that venous pressure determinations on the operating table may be useful to determine the possible deleterious effect on the lower leg should the femoral vein be divided at a given level. In this instance the marked rise in venous pressure when the common femoral vein was temporarily occluded made it seem inadvisable to divide the femoral vein at this site.

It is believed that venous pressure determinations are, by and large, more accurate than phlebograms to determine patency of the venous system.

The normal venous pressure at the foot or ankle with the patient in the supine position and the table tilted so that the anterior surface of the foot is level with the auricles is from 2 to 9 cm. of water.

There is such free venous anastomosis of the veins about the foot and ankle that the pressure is equal in any of the veins of this region, so that any available vein may be used to determine the venous pressure. The venous pressure in any vein at the foot will, when taken under the conditions described, give the venous pressure in the veins of the extremity in the aggregate at this level.

CONCLUSIONS

1. Determination of the venous pressure in the ankles and foot under basal conditions is a valuable procedure from a surgical standpoint.
2. When the femoral vein is acutely occluded by a clot the venous pressure at the ankle is elevated with the leg at rest.
3. If the venous pressure is normal at the ankle or foot after exercise, it may be stated that no massive occlusion of the venous system is present.
4. Further study of venous pressures is warranted to determine the usefulness and limitations of the procedure.

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SURGICAL CORRECTION FOR COARCTATION OF THE AORTA

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COARCTATION of the aorta is an abnormality which carries a variable prognosis. In some individuals such a blockage of the arterial pathway is compatible with a long and active life, but in others it leads to incapacitating complications or to a shortened life expectancy. Aneurysmal dilatation of the aorta, rupture of the aorta, or superimposed *Streptococcus viridans* infection is occasionally found. More commonly, the vascular obstruction produces an important hypertension (in the upper part of the body); with this may come various ill effects of the hypertensive state and possibly a fatality from cardiac failure or cerebral hemorrhage. While the general outlook for some of these patients is good, the prognosis for others is poor enough to justify attempts at surgical correction of the malformation.

At first, the desire to find a surgical cure for coarctation of the aorta seemed to have little chance of fulfillment. The technical difficulties in working on a vessel of this size were at once evident and, indeed, they appeared to be almost insuperable. In spite of such forebodings, it was decided to study the problem in the surgical laboratory and to define more clearly the handicaps which must be overcome. Beginning in 1938, attempts were made to practice the steps which would be necessary for removal of a segment of the thoracic aorta. Hufnagel later joined in this work and after encountering various disappointments, it was found that the upper part of the descending aorta could be adequately mobilized, that a section of it could be excised, and that the remaining ends of the aorta could be anastomosed in a satisfactory way. These experimental observations are recorded elsewhere.² Our researches on dogs indicated that the aorta could be completely transected and that a normal vascular pathway could be reconstructed. We became convinced that a similar procedure was fundamentally sound for the elimination of a coarctation of the aorta in human beings.

In each of the two cases herein reported, a narrowed and obstructed part of the aorta was resected and the continuity of the vessel was then re-established. In the first patient, the anastomosis was satisfactorily completed, and the aortic clamps were quickly removed. This sudden opening up of a huge vascular bed produced immediate cardiac dilatation and death. In the second patient, the aortic clamps were removed very slowly over a period of ten minutes so that the cardiac and circulatory readjustments were brought about more gradually. With this precaution, there were no deleterious effects on the heart, and the procedure was well tolerated.

CASE REPORTS

CASE 1.—P. S. was a 5-year-old boy whose primary complaint was frequent epistaxis since the first year of life. Examination showed a moderate hypertension in the arms and a deficient circulation in the legs. At operation, June 28, 1945, the aorta was found to be constricted just beyond the origin of the left subclavian artery, the lumen here being no more than 2 to 3 mm. in diameter. A section of the aorta about 5 cm. long was mobilized and specially prepared clamps were applied above and below the coarctation. A segment of

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vessel containing the anomalous area was then excised. The remaining ends of the aorta were united by a continuous mattress-type suture which included all layers of the aortic wall and which everted the edges of the aortic tissues. Upon removal of the aortic clamps there was satisfactory hemostasis at the line of anastomosis, but the quick release of blood into the great vascular bed of the lower part of the body imposed an enormous burden on the heart which dilated rapidly and ceased beating in a few moments in spite of all efforts to revive it.

CASE 2.—J. G. W. was a 12-year-old girl who was referred for study in the Peter Bent Brigham Hospital from March 5 to March 14, 1945.

The family history was irrelevant. The past history indicated that there had been some cystitis at 4 years of age and an attack of pyelitis at 9 years of age which was brought under control in about two weeks. A tonsillectomy had been performed at 8 years of age. A mild bronchopneumonia at 11 years had been treated with sulfonamides. Aside from these illnesses, the child had been a rather robust, cheerful, and active individual.

Illness at Time of Admission.—At 2 years of age, a heart murmur had been detected by the family physician. At 4 and 9 years of age, other physicians had again commented upon the presence of a heart murmur, but no description of it was available. From about 9 years of age until time of admission to the hospital, the patient had frequent frontal headaches, and had appeared more excitable and irritable than she had prior to that time. For some months there had been intermittent, mild epigastric distress for which the family physician had been consulted. The abdominal complaints were presumably related to constipation. On physical examination the blood pressure (in the arms) had been found to be elevated.

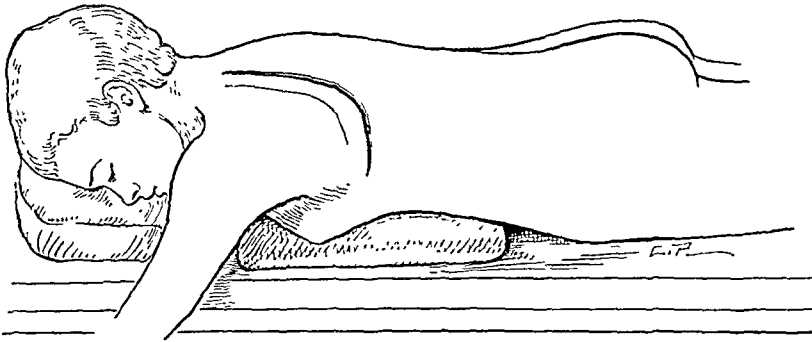


Fig. 1.—Position of patient on table and placement of cutaneous wound.

Hospital Course.—Among numerous other studies, it was found that no pulsation could be felt in the femoral, popliteal, or dorsalis pedis arteries. No blood pressure readings could be obtained in the legs. A hypertension was demonstrated in the arms. On most tests the systolic pressure varied between 188 and 198 mm. of mercury; the lowest figure was 160 and some observations ran as high as 220. On most determinations the diastolic pressure was between 110 and 120 mm. of mercury; the lowest figure was 98 and the highest was 152. The optic fundi showed marked tortuosity of the arteries and slight papilledema. All of these findings, combined with other extensive data, led to a diagnosis of coarctation of the aorta.

On July 5, 1945, the patient was admitted to the Children's Hospital.

Examination.—Physical examination showed a well-developed, well-nourished girl, possessing normal intelligence, and without complaints at the moment. The pulse was 98. The blood pressure in the right arm was 190 mm. of mercury systolic and 95 diastolic; in the left arm it was 190 systolic and 100 diastolic. No sounds could be heard over the popliteal vessels, and no pulsation of the mercury column could be seen in the sphygmomanometer, when blood-pressure readings were sought in the legs. No pulsation could be felt in the abdominal aorta, femoral regions, popliteal arteries, or dorsalis pedis arteries. Over the entire precordium a soft, systolic murmur of moderate intensity could be heard which was loudest over the aortic region. It was not accompanied by a thrill. Over the upper portion of the thorax posteriorly, a faint systolic murmur could be heard; this was loudest to the left of the spine, and was of less intensity than the murmur over the precordium. In the back, just medial to each scapula, pulsations could be felt in the subcutaneous tissues. In the base of the neck there were visible and heaving pulsations of the carotid arteries. In the supra-sternal notch was a forceful impulse presumably transmitted from the aortic arch.

Laboratory Data.—Urine examinations were negative. Hemoglobin was 91 per cent, red count 4.55 million cells per cubic millimeter; white count was 6,000 cells per cubic centimeter, blood smear normal. Roentgenographic examination showed a total transverse cardiac dimension of 9.9 cm. and an internal transverse diameter of the thorax of 25.7 cm. The heart did not appear to be enlarged and there was no detectable abnormality of the left ventricle. The aortic knob could not be clearly visualized. The lungs were normal. In the posterior portion of the chest there was a notching along the inferior borders of several ribs.

Operation.—Operation was undertaken July 6, 1945. Cyclopropane with a tightly fitting face mask, without an intralaryngeal tube, proved to be quite satisfactory. A cannula was inserted into an ankle vein for administration of fluid and blood during and after the operative procedure. The patient was placed on the table so that the left posterolateral portion of the chest was uppermost. A long, curved incision was made, beginning just to the left of the spine, starting at the level of the second rib and running downward and outward to reach the posterior axillary line at about the level of the inferior tip of the scapula. Beneath

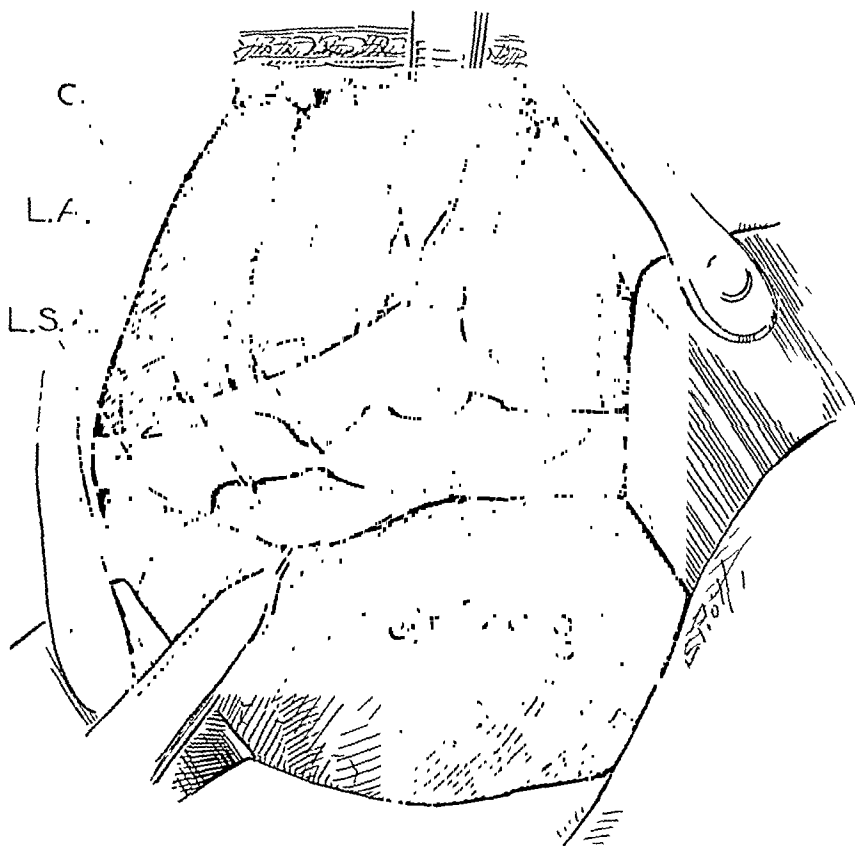


Fig. 2.—General view of operative field. Pleural cavity entered through fourth intercostal space. Aorta exposed by opening its overlying parietal pleura. For clarity, the vagus nerve has been omitted. C, Coarctation of aorta; L.A., Ligamentum arteriosum; L.S.A., Left subclavian artery.

this incision the muscles were divided, including the trapezius, the rhomboid major, and the latissimus dorsi, so that the scapula could be pulled upward and outward to expose the costal cage. The left pleural cavity was entered in the fourth interspace. The third, fourth, fifth, and sixth ribs were transected at their angles. These initial stages of the operation entailed a considerable loss of blood because of the excessive vascularity of the chest wall. The large intercostal arteries were not difficult to control, but there was very troublesome bleeding from the external musculature which consumed a good deal of time in obtaining proper hemostasis.

With the insertion of a self-retaining rib spreader, a satisfactory view of the posterior part of the mediastinum was obtained. The aorta was exposed by opening and dissecting free its overlying parietal pleura. The descending aorta, about 1.5 cm. below the origin of the left subclavian artery, was markedly constricted, the external diameter being no more than 3 or 4 mm. (Fig. 2). Palpation of this region gave the impression that it was a firm and completely fibrous cord, and that it contained little or no lumen. Immediately above the con-

stricted site the aorta was approximately 15 mm. in diameter, while beyond the coarctation it was 13 to 14 mm. in diameter. Above the constricted area, the aorta and the entire aortic arch had a marked and heaving pulsation which was transmitted prominently into a dilated left subelavian artery. Below the obstructed part of the aorta the vessel had no visible or palpable pulsation. The intercostal arteries coming into the aorta below the coarctation were distinctly larger than normal, most of them being 4 to 6 mm. in diameter. The uppermost vessels running into the aorta below the coarctation appeared to be the fourth intercostal arteries. The distal part of the aortic arch was now freed from the posterior chest wall and

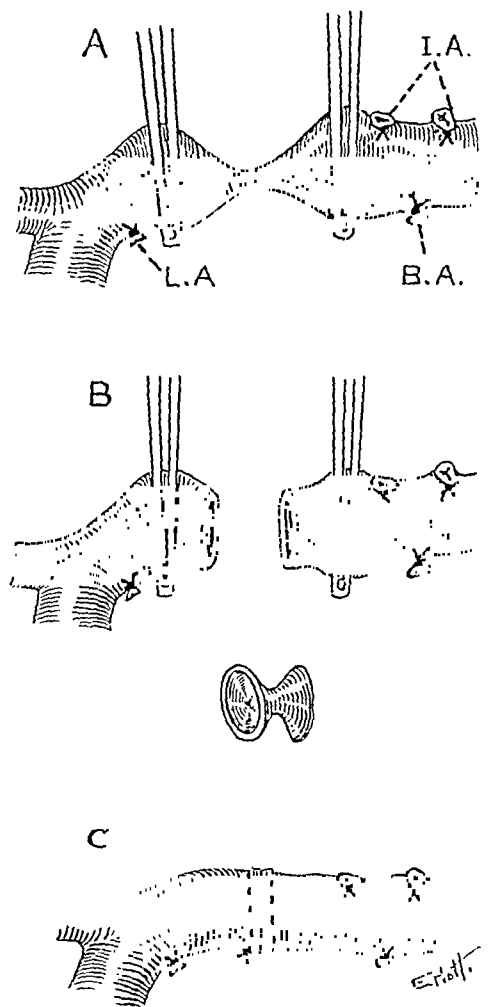


Fig. 3.—A, Section of aorta mobilized by freeing it from its bed and dividing regional intercostal arteries (I.A.), bronchial artery (B.A.), and ligamentum arteriosum (L.A.). Clamps applied to aorta. B, Segment of aorta excised. C, Aorta reconstructed by end-to-end anastomosis, with continuous, everting, mattress-type silk suture.

vertebral column by careful dissection, particular care being taken to visualize and avoid injury to the vagus nerve, the left recurrent laryngeal nerve, and the thoracic duct, all of which were satisfactorily viewed. To free the aorta for a short distance below the region of coarctation, it was necessary to doubly ligate and divide the left and right fourth and fifth intercostal arteries. Furthermore, in order to free the aorta from the lung root, a bronchial artery was severed. The ligamentum arteriosum was then cut. All of this dissection was completed without much difficulty.

The upper 3 or 4 centimeters of the descending aorta could now be pulled away from the vertebral column and could be drawn out from the depths of the wound so that the subsequent steps were more easily completed. Two especially prepared clamps were placed on the aorta, just above and below the constricted zone (Fig. 3A). Application of these clamps produced absolutely no changes in the heart rate or activity. A segment of aorta, 1 cm. long, was then excised so that the narrowed portion was completely eliminated. (Inspection of the interior of this specimen showed that there was a complete blockage of the lumen.

The wall was quite thick, firm, and fibrous.) The remaining ends of the aorta were now brought in apposition to each other by applying pressure in the appropriate direction to the two clamps which held the aorta. The upper and lower segments possessed a great deal of elasticity and the undivided attention of the first assistant was required to hold these clamps in proper alignment. Dr. Paul Ware had previously practiced these steps with me on dogs, and his assistance at this time greatly facilitated the anastomosis of the aortic ends which was accomplished rapidly, with accuracy, and without the slightest tension on the line of suture while the stitching was being undertaken. The type of repair was precisely that which previously has been found to be suitable in animal experiments and which has been fully reported elsewhere.² The ends of the aorta were brought together by a continuous mattress suture which included the full thickness of the aortic wall and which everted the aortic wall so that intima came to intima, and the edges of the aortic ends protruded outward. This continuous stitch was begun posteriorly and was continued around on the front surface. For this suture, 00000 Deknatel silk was employed, carried on a No. X atraumatic curved needle (which has a diameter of 0.5 mm. and a length of 9 mm.). The anastomosis required twenty-three minutes. Manual pressure was relaxed from the clamps at this time so that the suture line took up the entire pull of the aortic elasticity.

The lower clamp was then removed, and as blood flowed back from the lower segment up into the anastomosis, there was oozing of a few drops of blood at one point, which was readily controlled with the application of a pack for a few moments. Following this there was not the slightest bleeding from the suture line at any time. In three ways great care was exercised to insure that there would be no abrupt shift of the circulating blood which might embarrass the heart. First, the remaining aortic clamp was released very slowly over a period of ten minutes so that the lumen of the aorta was opened very gradually. This was done in order to avoid a great rush of blood into the lower part of the body. Second, the table was tilted to place the patient in mild Trendelenburg position, to diminish pooling of blood in the legs and lower part of the body, and to increase the return of venous blood to the heart. Third, donor blood was pumped rapidly into the ankle cannula in order to augment the blood in the venous system and to make available an adequate volume for the heart to circulate. These three measures combined to minimize the strain on the heart during the period of readjustment and the effects were completely satisfactory. During this time the heart rate increased slightly but at no time did the organ appear to be overtaxed. It was very gratifying to see that the distal aorta had a visible and palpable pulsation.

The field was completely dry, and the cardiovascular system was well stabilized, hence closure of the wound was begun. The parietal pleura was brought together over the aorta with interrupted fine silk sutures. The thoracic wound was appropriately repaired. A catheter was placed in the left pleural cavity, and just before the suture of the skin was completed, suction was applied to this tube for the removal of all air from the left pleural cavity; the catheter was then withdrawn. The operating time was three hours, thirty-five minutes.

Post-operative Course.—There were no important complications. There was a good deal of pain from the posterior chest wound which required frequent sedation for the first week; continued but less intense medication was necessary during the second week. During each of the first four postoperative days, 120,000 units of penicillin were administered by the intramuscular route. No heparin or dicumarol was given at any time. Twelve days after operation the red blood count showed an anemia, for which three small transfusions were given. These raised the count to 4,250,000 cells per cubic millimeter. On the eighth day the child was allowed up in a chair and on the eleventh day was permitted to walk a little. She was discharged from the hospital on the nineteenth postoperative day in excellent general condition. There had been some postoperative accumulation of fluid within the left pleural cavity, but by the time of hospital discharge the breath sounds throughout the left lung field were of normal intensity and apparently most of the fluid had disappeared. The chest was not tapped at any time. The wound healed per primam.

Great interest was centered around the circulatory and blood pressure changes during the postoperative period. The cardiac murmur has continued unchanged from its preoperative state, and I assume that it arises from some minor, intracardiac abnormality, the nature of which is not clear. It may possibly represent a bicuspid aortic valve. I had anticipated that the pressure in the arms would fall suddenly, and similarly that the pressure in the legs would rise quickly following the aortic anastomosis. However, this was not the case. The observations make it evident that the readjustment occurred over a period of several days, and indeed continued for about two weeks. Presumably the vascular bed beyond the obstructed

portion of the aorta had been smaller than normal prior to operation and had required a period of time to undergo dilatation following removal of the aortic obstruction. In any event, the flow of blood into the legs did not increase rapidly and, indeed, required many days to reach a satisfactory level, concomitant with which the pressure in the arms became correspondingly lower.

At the termination of operation, no femoral pulsation could be felt. Furthermore, no sounds could be heard in the legs when attempts were made to observe the blood pressure. Six hours after completion of operation, a very faint and barely detectable pulsation could be felt in the femoral arteries, but no blood pressure readings could be obtained in the legs. On the following morning femoral pulsations appeared to be a little stronger and in the right leg, faint sounds could be heard at 110 mm. of mercury, but the diastolic level was indeterminate. No sounds could be heard in the left leg. By the evening of the second postoperative day, there were rather good, but not normal, femoral pulsations and the blood pressure in both legs was clearly audible at a systolic level of 125 mm. of mercury and a diastolic level of approximately 90 mm. of mercury. On the eighth postoperative day, the femoral pulsations were a little stronger, no popliteal pulsation could be felt, but faint pulsations could be felt in both dorsalis pedis arteries. At this time the pressure in the right leg was heard at 118 mm. of mercury systolic and 100 diastolic. In the left leg the pressure was 122 mm. of mercury systolic and 104 diastolic. At the time of hospital discharge on the nineteenth postoperative day, there were fairly good femoral and dorsalis pedis pulsations on both sides. The pressure in the legs was recorded at 145 mm. of mercury systolic and 105 diastolic.

While the observations in the last paragraph indicated that there was an increase in circulation in the lower extremities during the postoperative period, there was a simultaneous diminution in the pressure readings in the arms. On the day after operation, the highest blood pressure recorded was 175 mm. of mercury systolic and 100 diastolic. During the following week a large number of observations showed systolic pressures ranging from a high of 170 to a low of 138. During the second postoperative week, there was a gradual decline in the readings which varied between 150 and 145 mm. of mercury systolic and 85 to 75 diastolic. At the time of hospital discharge, the blood pressure was recorded as 140 systolic and 80 diastolic.

SUMMARY

Laboratory experiments on dogs have demonstrated the feasibility of removing segments of the thoracic aorta and re-establishing the arterial channel by end-to-end suture of the vessel. The high degree of success attained with such a procedure on animals has prompted its use in human subjects for correction of obstruction of the aorta.

In two patients with coarctation of the aorta, the narrowed portion has been excised and the aortic tube has been reconstructed by direct anastomosis of the remaining ends. In the first case, sudden removal of the aortic clamps opened a large vascular bed and produced cardiac dilatation and immediate death. In the second child, a slow release of the clamps and a gradual increase in the blood flow to the lower part of the body was well tolerated. In this individual there has been a very satisfactory postoperative rise of blood pressure in the lower extremities and a concomitant decrease of the hypertension which had previously existed in the arms and upper portion of the body.

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ARTERIOVENOUS FISTULA: A SUTURE TECHNIQUE FOR PRODUCING A LATERAL ANASTOMOSIS

AN EXPERIMENTAL STUDY

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EXPERIMENTAL vascular surgery by the suture method appears to have begun about 1773 when Asman¹ unsuccessfully attempted vascular suture in two animals after the development of the new clinical technique of Hallowell² in 1759 and Lambert³ in 1762. Infection, hemorrhage, and thrombosis dogged the footsteps of subsequent investigators. While there were isolated clinical cases of successful vascular repair, it was not until after the introduction of aseptic surgery that experimental work met with any success. In 1883 Gluck⁴ did nineteen experiments, using the common iliac artery of dogs and the aorta of rabbits, but all of them terminated in hemorrhage. Four years later, von Horoch⁵ began a series of six experiments on arterial suturing but in each case the vessels thrombosed.

It was in 1889 that Jessinewski^{6, 7} demonstrated by twenty-six experiments terminated in from 1 to 100 days that arteries could be sutured successfully, provided certain precautions were heeded. He placed emphasis on the importance of keeping the suture from penetrating the intima. In the next year Burci⁸ reported attempts to repair longitudinal wounds in the arteries of six animals, using femoral and carotid arteries of dogs and horses. His success in four cases confirmed the findings of Jessinewski. Subsequently he suggested the use of the continuous suture. In 1890 Muscatello⁹ reported success in suturing the aorta of a dog in which there had been transverse division of one-third of the wall of the vessel. Following the precepts of Jessinewski, success was reported by Heidenhain¹⁰ in 1895, Jaboulay and Briau^{11, 12} in 1896, Salomoni¹³ in 1900, and Napalkow¹⁴ in 1900. Murphy¹⁵ in 1897 reported further suture experiments and reviewed two clinical cases. In 1897 and 1898 Silberberg,¹⁶ using Hagedorn intestinal needles and fine silk, had moderate success in suturing the arteries of dogs.

In 1899 Dörfler¹⁷ contributed materially to the progress of vascular surgery when he demonstrated that, with rigid adherence to aseptic technique, successful through-and-through suturing of blood vessels was possible. In his dogs, the vessels remained patent, even in those killed after two months. Thus was dispelled the fear that thrombosis was an inevitable consequence of penetrating the intima. Soon after this notable discovery came the outstanding work of Carrel,¹⁸ of Carrel and Morel,^{19, 20} of Carrel and Guthrie,²¹ and of Guthrie,²² whose experiments at the turn of the century set the standards for a reliable technique for vascular surgery. There have been minor improvements and modifications by Clermont,²³ Jensen,²⁴ Dorrance,²⁵ Bernheim,²⁶ Williamson,²⁷ Voss,²⁸ Mann,²⁹ Markowitz,³⁰ and Corwin³¹ among others.

While thrombosis and subsequent healing in clinical cases of acquired arteriovenous aneurysm are rare,³² this is not true of experimentally produced fistulas. The literature abounds with references to either a high percentage of thromboses and healing or complete failure to maintain a patent fistula.

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While Eck³³ in 1879 is generally regarded as the first to anastomose adjacent vessels with success, Gluck⁴ in 1883 reported the first successful arteriovenous fistula in a dog. In 1898 San Martin y Satrústegui³⁴ attempted to invaginate the artery into the vein in forty dogs but closure by thrombosis ensued in from a few hours to the longest period of eight days. He then tried two lateral anastomoses of the vessels of goats and again failed. Carrel and Morel^{19, 20} in 1902 and Carrel and Guthrie²¹ in 1906 admitted varying degrees of success. In 1907 Watts³⁵ reported success in twenty-eight of thirty-one end-to-end arteriovenous anastomoses of the vessels of the neck but in only two of twelve of the femorals. The poor results in the latter, he felt, were due to easy accessibility and subsequent infection in the hind limb. In 1920 Reid³⁶ reported healing in seven of twelve dogs with marked diminution in the size of two of the remaining fistulas. Reference was made several times by Holman and Kolls³⁷ in 1924 and by Holman³⁸ in 1937 to closure of their experimental fistulas. In 1925 S  n  que³⁹ reported complete failure to produce fistulas in ten dogs, for thrombosis always obliterated the venous channel. In 1928 Herrmann and Gage⁴⁰ likewise produced thrombosis within one or two days at the site of anastomosis. They made two or three attempts in the same animal for a caroticojugular fistula. One fistula remained open for forty days. In 1938 Corwin³¹ reported success with six out of ten end-to-end anastomoses of carotid artery to jugular vein, but the two lateral arteriovenous anastomoses broke down with hemorrhage in three and eight days. In 1940 McGuire, Hauenstein, Stevens, and Sharretts⁴¹ observed closure of one in a series of six dogs with femoral arteriovenous aneurysm. Likewise, thrombosis has followed the practice of suturing the vessels over dilator plugs of caramelized dextrose, a procedure recently advocated by Smith⁴² but discarded by Carrel¹⁸ in 1902. This technical problem has been summed up by Brooks,⁴³ who stated: "In the experimental laboratory, a permanent arteriovenous fistula is very difficult to produce. In animals, even comparatively large fistulae, established by careful blood vessel suture, in most instances close spontaneously."

The great number of vascular casualties of World War II already under treatment should act as a stimulus, as in the last war, to experimental studies in a further effort to clarify many physiologic complexities which as yet remain unsolved. Since this is particularly true of arteriovenous fistula, I wish to present the technique of vascular suture used in the production of femoral arteriovenous fistulas from 1 to 4 cm. in length in a consecutive series of fifty-two dogs, with periods of observation of from one week to one year, without a single case of closure. The majority of the animals were killed between seven and nine months after production of the fistula.

TECHNIQUE

Ideally, fairly large dogs should be used since the caliber of their vessels facilitates experimental suture methods. However, several of our dogs weighed only 7 kilograms. We found that ether administered by inhalation or pentobarbital sodium administered intravenously produced equally satisfactory anesthesia. It is essential that the surgeon exercise the same sterile precautions as in the hospital operating room.

If the skin flap is prepared so as to overlies the vessels at the time of closure, the chances of postoperative infection are lessened. After the skin field has been isolated by sterile gauze or linen, the vessels are exposed, cautiously avoiding small tributaries which are easily torn. A blunt curved aneurysm needle is helpful at this stage for separating the tough strands of the sheath. The most

satisfactory arteries in the dog are the femorals, common iliaes, carotids, and aorta.

After the desired segment of artery and vein has been exposed, all adventitial tissue is removed scrupulously, as this tenacious weblike tissue drawn into the lumen with the suture acts as a nidus for thrombus formation. Small vessels arising from the exposed length of the vessels selected for the fistula are ligated to avoid troublesome bleeding during the suturing. Drying is avoided by occasionally washing the field with warm saline solution or liquid petrolatum. This also facilitates removal of the adventitia. If the vessels are mobilized for several centimeters proximal to the anastomosis, the shearing or sawing stress on the suture line by the forceful arterial pulsation is lessened.

Before the vessel walls are incised, one Carrel clamp is placed proximally and one distally to the site of anastomosis. The rubber or silk-shod blades should have moderate spring, as intimal damage from serrefines has led to thrombosis (Jaboulay and Briau). Iris scissors with straight blades seemed to give a cleaner cut than a keratome and avoided damage to the deep walls. The longitudinal incisions should lie in careful juxtaposition so that no torsion of the

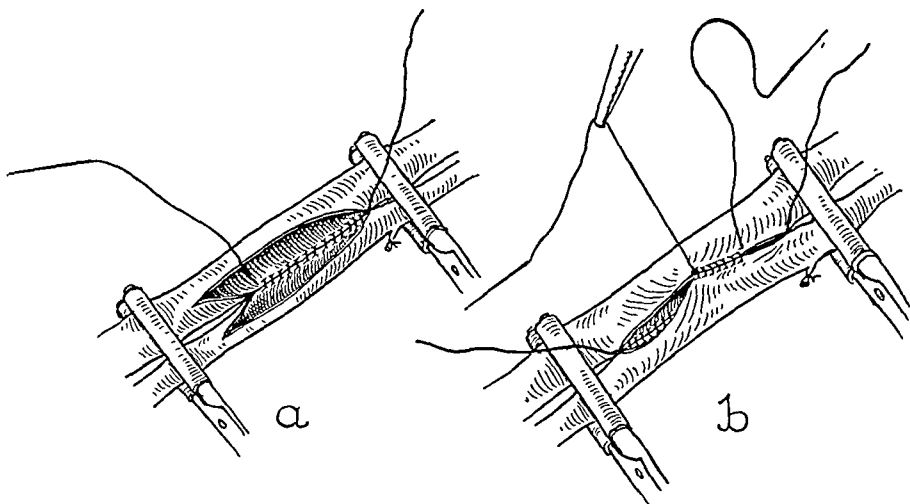


Fig. 1.—Experimental production of arteriovenous fistula. *a*, Suturing of deep margins of artery and vein. *b*, Suturing of superficial margins.

vessels occurs during suturing, for intimal damage can result from this mishandling. One should not cut within 5 mm. of the clamps; if this precaution is not observed, adequate closure of the angles is difficult. With the lumina of the vessels exposed, sterile liquid petrolatum is instilled into both artery and vein before suture is begun to reduce adherence of platelets. Rough handling of the vessels should be avoided at all times. Very fine (000) twisted white silk, threaded on a single straight Carrel arterial needle (previously sterilized as a unit in liquid petrolatum), is used for the deep margins. Beginning at the cephalad end the angles are approximated and a knot is tied. Using a running through-and-through stitch, one takes bites to the depth of twice the diameter of the needle and 1 mm. apart. Care is taken to keep the suture coated with petrolatum and to pull the thread taut after each bite. The edges should be everted as well (Fig. 1*a*). Bull dog clamps are used to mark the ends of the silk at the completion of suturing the deep margins. By using a single suture without a stay tension suture for the deep margins, twisting of the vessels, which occurs with the usual technique, is obviated. Here again, intimal damage is avoided.



Fig. 2.—Dissected specimen showing femoral arteriovenous anastomosis after one year. Note dilatation of proximal and distal portions of vein and also of vena cava.



Fig. 3.—*a*, Small fresh thrombus at site of anastomosis after one week. *b*, Endothelialized fibrous tissue at site of anastomosis after nine months (Mallory-Heidenhain stain $\times 40$).

A second suture, threaded at both ends on arterial needles, is run through the approximated artery and vein midway along the superficial margins and a knot is tied. Using the free end of the suture for retraction and for maintaining dilating action, the surgeon can continue the closure to the cephalad end where a firm knot with the deep suture seals the angle (Fig. 1b). The remaining free end is then used to complete closure to the distal angle. By using this second suture one avoids the purse-string effect of a single suture technique, thus reducing cicatricial contraction (Figs. 2 and 3).

If care is taken to close the angles carefully there should be but momentary mild bleeding from the suture lines on removal of the distal clamp. If digital pressure for several minutes fails to halt bleeding, an additional interrupted suture may be taken. The proximal clamp is released last. Both the muscle layer and the subcutaneous tissues are approximated separately with continuous chromic catgut. We have closed the skin with continuous linen suture and applied collodion gauze to the suture line of the skin.

SUMMARY

1. A brief review of experimental vascular surgery is presented and the difficulties in production of experimental arteriovenous fistulas are pointed out.

2. A modification of the Carrel-technique is outlined whereby (a) by allowing the skin flap to cover the deep layers and the anastomosis, chances of infection are lessened; (b) dilatation is maintained by a tension suture but torsion of the vessels is avoided; (c) by use of two sutures, the contracting effect of a purse-string type of suture is eliminated; (d) by mobilizing a suitable length of the vessels proximal to the anastomosis, the sawing stress on the suture line is buffered.

3. This technique was used successfully to produce arteriovenous fistulas, varying from 1 to 4 cm. in length, in a series of fifty-two dogs weighing from 7 to 18 kilograms without a single closure by healing, infection, or thrombosis.

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SUCCESSFUL REMOVAL OF FOREIGN BODIES WITHIN THE PERICARDIUM

A REPORT OF TWO CASES

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INASMUCH as the thought concerning the proper management of foreign bodies within the pericardial sac remains indefinite and indecisive²⁻⁴ we should like to report two cases in which the patients were treated by successful surgical removal, in addition to one case¹ previously reported.

CASE 1.—This soldier, aged 21 years, was first admitted to an evacuation hospital, Feb. 29, 1944, within six hours after receiving a perforating wound of the left arm and a penetrating wound of the left side of the chest by an enemy high explosive shell fragment. This injury resulted in a compound, incomplete fracture of the left humerus, a partial paralysis of the left median nerve, a left hemothorax, and a nonpenetrating wound of the left ventricle of the heart, producing a hemopericardium. The wound of the left arm was débrided, the left ventricular laceration was repaired, and the pericardium sutured, but the foreign body was not removed. The immediate postoperative course was uneventful and he was transferred to this hospital March 12, 1944, in good condition, twelve days after injury.

Physical examination on this day showed a well-developed, somewhat emaciated white man, slightly dyspneic and with moderate neck vein distention. The temperature was 100° F., pulse 100 per minute, respirations 24 per minute, and blood pressure 130/66. The chest showed slight limitation of expansion on the left side with impaired resonance and distant breath sounds in the left base. The heart tones were normal in volume and no murmurs were present. Examination of the abdomen was negative. There was a partial paralysis of the left median nerve and an incomplete fracture of the lower third of the left humerus.

Laboratory studies revealed hemoglobin, 12 Gm.; red blood cells, 3,600,000; white blood cells, 10,000; polymorphonuclears, 73 per cent; lymphocytes, 26 per cent; monocytes, 1 per cent. Urine: Specific gravity, 1.022; chemical tests and microscopic studies were negative. The sedimentation rate was 55 mm. in one hour (Wintrobe), the venous pressure 185 mm. of water in the right antecubital vein, and the circulation time from the same area using 10 per cent calcium gluconate was 12 seconds.

Fluoroscopic study, March 13, 1944, showed good forceful pulsations of all borders of the heart with definite to-and-fro pulsation of the left border. The base of the heart appeared a little enlarged but did not change in contour when the patient shifted from the prone to the upright position. There was no evidence of cardiac tamponade at this time. The metallic foreign body was seen to lie just to the left of the midline and anterior to the heart. X-ray examination of the chest (Fig. 1) showed a density in the lower left lung field with a concave upper border, very suggestive of a small left pleural effusion. The cardiac shadow appeared enlarged with widening at the base, but a part of this apparent enlargement was due to the fact that this view was taken in the anteroposterior diameter at a short target distance. There was a metallic foreign body 2 by 1 cm. lying just to the left of the midline, just beneath the lower border of the sternum, and about one inch above the left diaphragm. It was thought that the foreign body was anterior to the heart on these roentgenograms.

Fluoroscopic study, March 25, 1944, showed normal pulsations of the heart and the foreign body moved synchronously with each heartbeat. A teleoroentgenogram and left lateral x-ray picture of the chest on the same day showed a reduction in the size of the cardiac shadow and the location of the foreign body. (Figs. 2 and 3.)

An electrocardiogram made March 12, 1944 (Fig. 5 A), showed the T wave in Lead 4 to be inverted and in Leads 1 and 2 low or isoelectric. Thereafter, frequently repeated tracings showed no essential change until March 17, 1944 (Fig. 5 B), when the T waves in

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Leads 1 and 2 became inverted and the S-T segments in these leads rounded and upwardly convex. Subsequent tracings showed no further change until after the operation.

As a result of these findings it was tentatively decided that the foreign body should be removed from the pericardial sac. In preparation for the operation the left side of the chest was aspirated on two occasions, 300 c.c. of bloody fluid being removed March 20, 1944,

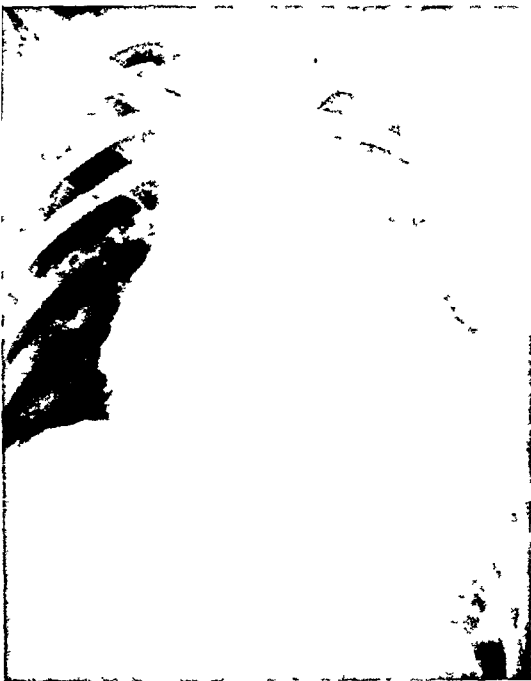


Fig. 1.



Fig. 2.

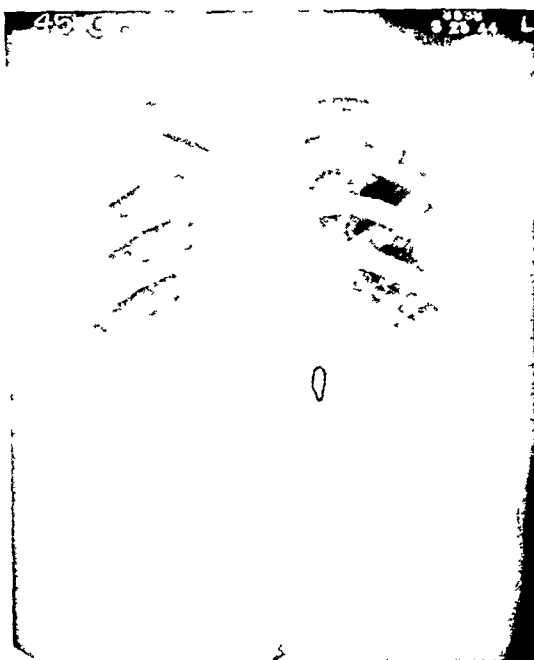


Fig. 3

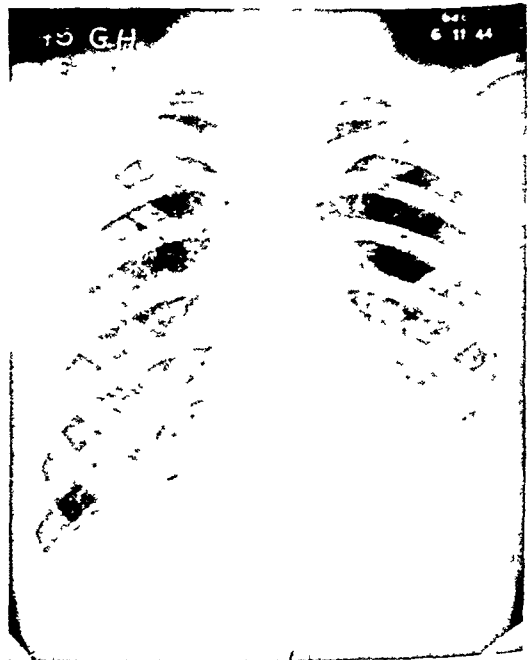


Fig. 4.

Fig. 1 (Case 1)—Roentgenogram, March 13, 1944, shows enlargement of the cardiac shadow and a small left hemothorax. Foreign body not shown in this view.

Figs. 2 and 3 (Case 1)—Roentgenograms, March 25, 1944, show the foreign body within the pericardium lying on the anterior surface of the right ventricle. Fluoroscopy disclosed movement of the fragment with each heartbeat.

Fig. 4 (Case 1).—Roentgenogram, June 11, 1944, shows the return of the cardiac shadow to normal size and configuration. Foreign body removed April 7, 1944.

and 20 c.c. of serous fluid March 26, 1944. The patient was given one transfusion of 500 c.c. of blood and general supportive treatment with iron, vitamins, and supplementary diet as far as facilities would allow. These measures resulted in weight increase, improvement in respiration, disappearance of neck vein distention, increase in the red blood cell count to 4,400,000 and the hemoglobin to 13.5 Gm., a fall in the sedimentation rate to 9 mm. in one hour (Wintrobe), and a decrease in the venous pressure to 95 mm. of water, as measured in the right antecubital vein. Other studies made prior to operation showed a hematocrit of 44.5 per cent and a serum protein of 6.5 Gm. Physical examination and special studies of the heart and vascular system remained essentially unchanged.

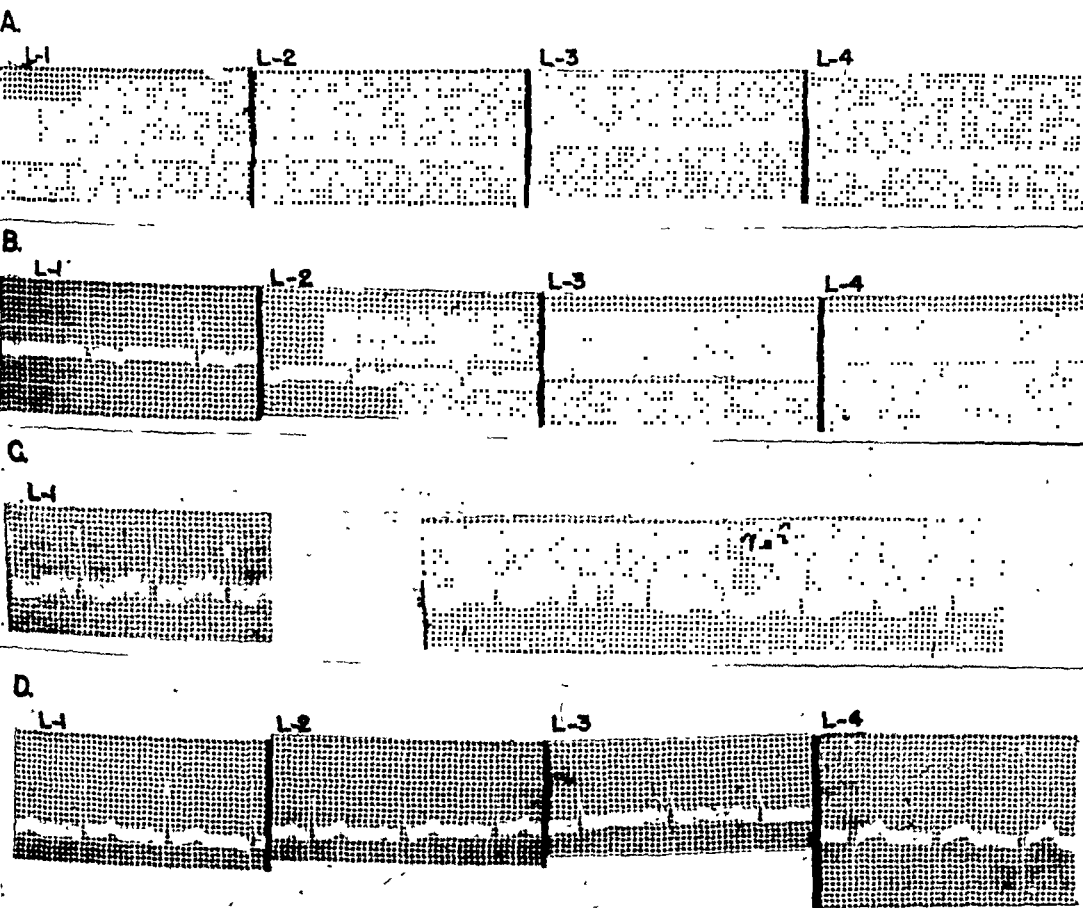


Fig. 5.—A, March 12, 1944. Rate: Auricular, 120 per minute; ventricular, 120 per minute. P-R interval, 0.14 second; rhythm, normal. QRS complexes: 0.08 per second; QRS 3 low and inverted. T waves: T₁ low and diphasic; T₂ low; T₃ isoelectric; T₄ inverted.

B, March 17, 1944. Rate: Auricular, 90 per minute; ventricular, 90 per minute. P-R interval, 0.12 second; rhythm, normal. QRS complexes: 0.08 per second; QRS 3 upright. T waves: T₁₋₂₋₄ inverted; T₃ isoelectric.

C, April 7, 1944 Rate: Auricular, 130 per minute; ventricular 130 per minute. Interpretation: Tracing taken at time foreign body was being removed from the pericardium. Demonstrates a sinus rhythm.

D, May 8, 1944. Rate: Auricular, 110 per minute; ventricular, 110 per minute. P-R interval: 0.12 second; rhythm, normal. QRS complexes: .08 per second; normal. T waves: T₃ low; T₁₋₂₋₄ upright.

April 7, 1944, under endotracheal nitrous oxide, oxygen and ether anesthesia, a left parasternal incision for an extrapleural approach was made extending along the left sternal margin from the second interspace to the sixth rib and along the upper border of the sixth rib to the nipple line. The skin-fascia-muscle flap was turned up to expose the third, fourth, and fifth costal cartilages and the anterior ends of the corresponding ribs. The fourth costal cartilage and the anterior 2 cm. of the corresponding rib were resected subperichondrally and subperiosteally. The posterior perichondrium and intercostal bundle were divided near the sternum and retracted, to expose the internal mammary vessels which were doubly ligated proximally and distally with No. 1 chromic catgut and resected between the ligatures. The communicating intercostal vessels were also ligated. The loose tissue anterior to the pericardium was incised near the sternal border and stripped laterally with the pleura. The

foreign body at this stage could be palpated at the sternal margin just below the lower border of the third costal cartilage. The pericardium over the fragment, which was lying on the upper anterior wall of the right ventricle was carefully incised, the metallic fragment grasped with forceps and gently removed. There was considerable fibrous tissue reaction about the fragment with adhesions between the pericardium and right ventricular wall in that vicinity. There was no bleeding and no pus was encountered. Sulfanilamide powder was sprinkled into the pericardial cavity. The pericardium was loosely closed with No. 0 chromic catgut sutures. The chest wall was closed in layers using No. 1 plain catgut to approximate the posterior perichondrium at its site of division at the sternal margin; No. 1 plain catgut interrupted sutures for the pectoral sheath; No. 00 catgut for the subcutaneous tissue, and black silk for the skin.

The postoperative course was uneventful with the patient out of bed on the fourteenth day. An electrocardiogram taken May 8, 1944 (Fig. 5 D), showed upright T waves in Leads 1-2 and 4 as compared to inverted T waves in these leads prior to operation. This tracing was otherwise normal and tracings taken at weekly intervals thereafter until the patient's discharge were likewise normal. X-ray and fluoroscopic studies June 11, 1944 (Fig. 4), showed the transverse diameter of the heart to be 12 cm., the transverse diameter of the thorax 29.5 cm., and the cardiothoracic ratio 40 per cent. There was some straightening of the left border of the heart, but the cardiac shadow was not enlarged. June 14, 1944, examination showed the heart rate 82 per minute, the rhythm regular, the blood pressure 122/76, and the tones of good quality. The thoracic wall at the operative site was well healed, firm, and showed no evidence of bony or cartilaginous defect. The wound of the left arm and humerus was completely healed and there was full restoration of function of the left median nerve.

He was discharged to limited duty June 16, 1944, nine weeks after operation and three and one-half months after he was wounded.

CASE 2.—This soldier, aged 21 years, was wounded 5:15 P.M., May 31, 1944, by an enemy machine pistol bullet, which entered the right anterior chest just below the middle third of the right clavicle. The patient was admitted promptly to a field hospital, dyspneic and cyanotic. Four hours after being injured, the right side of his chest was aspirated and 150 c.c. of blood removed. Following this it was noted that he was resting more comfortably, although still complaining of slight pain in the right side of the chest. On the following day the wound was debrided and the chest again aspirated, 100 c.c. of blood being obtained. The patient's condition improved sufficiently for him to be evacuated to the rear on the fourth day after injury.

On admission to this hospital, June 4, 1944, physical examination showed the patient to be in fair general condition with a clean debrided wound, 3 by 2 cm. in size, on the right anterior chest wall in the first interspace below the middle third of the right clavicle. He was dyspneic, with respirations 48 per minute, and slightly cyanotic. The temperature elevation was to 102.4° F., and the pulse rate 112 per minute, and the blood pressure in the right arm 114/72, in the left 120/82. The neck veins were slightly distended with the patient in the recumbent position. Bronchial breathing was present in both bases posteriorly below the angle of the scapulae. The heart tones were distant and the area of cardiac dullness was enlarged to the left. The liver edge was firm, nontender, and extended 6 cm. below the costal margin. No evidence of peripheral edema was detected.

Laboratory studies revealed red blood cells, 3,500,000; hemoglobin, 13 Gm.; white blood cells, 7,000; polymorphonuclears, 58 per cent; lymphocytes, 40 per cent; eosinophiles, 2 per cent. Urine: Specific gravity 1.019; chemical tests and microscopic studies were negative.

X-ray (Fig. 6) and fluoroscopic studies June 6, 1944, showed an enlarged cardiac silhouette, pulsating weakly, which was not altered by changing the patient's position from the upright to the recumbent. A 1.7 by 1 cm. opaque foreign body was lying in close proximity to the left border of the heart shadow. There was a moderate collection of free fluid in the right pleural cavity.

June 7, 1944, there was noted a definite narrowing of pulse pressure with a reading of 110 systolic over 85 diastolic. The heart tones were more distant, the neck veins showed more distention, a pulsus paradoxus was present, and the liver edge was still found 6 cm. below the right costal margin. The venous pressure in the right antecubital vein was 210 mm. of water and the circulation time using 10 per cent calcium gluconate was 35 seconds from the same area.



Fig. 6.

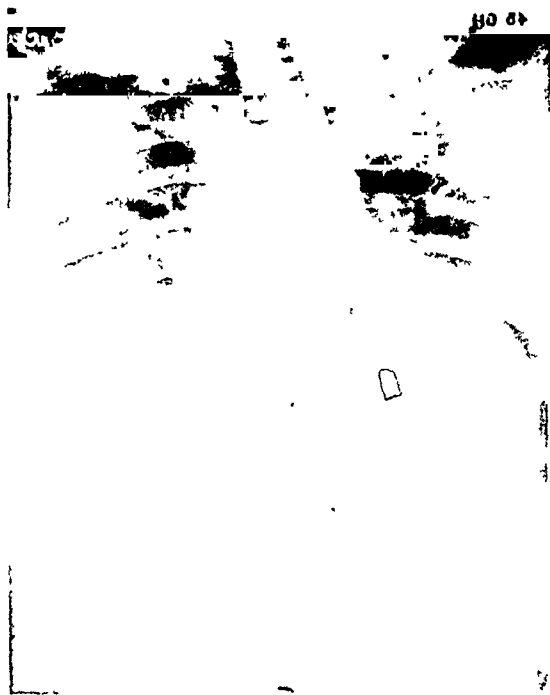


Fig. 7.



Fig. 8.

Fig. 6 (Case 2).—Roentgenogram, June 6, 1944, shows an enlarged cardiac shadow and bullet.

Fig. 7 (Case 2).—Roentgenogram, June 8, 1944, shows reduction in the size of the cardiac shadow following pericardicentesis, and fluid in the right pleural cavity. Fluoroscopy disclosed synchronous motion of the bullet with each heart-beat and frequent change of position in the pericardial sac.

Fig. 8 (Case 2).—Roentgenogram, June 16, 1944, shows the bullet along the right border of the heart, and further decrease in the size of the cardiac shadow. There is complete clearing of the right pleural cavity and lung following one aspiration of 510 c.c. of bloody fluid, June 9, 1944.

In view of these findings, a diagnosis of cardiac tamponade was made, and, June 7, 1944, a pericardicentesis was done removing 705 c.c. of old bloody fluid. Following this procedure the patient noted prompt improvement in his breathing, the cyanosis disappeared, and the pulse pressure widened with the blood pressure now reading 114/72. The next day a pericardial friction rub was noted which lasted for a period of three days. The patient continued to feel more comfortable, the dyspnea was much less marked, the neck vein distention disappeared, the liver decreased in size, and the pulse pressure remained at a normal figure. June 8, 1944, fluoroscopic and x ray studies (Fig. 7) showed a reduction in the size of the heart shadow with the presence of a more active pulsation. The opaque foreign

body was localized within the pericardial sac and shifted with the position of the patient. There was still the same collection of fluid in the right pleural cavity, and 510 c.c. of old bloody fluid were removed, June 9, 1944, by thoracentesis through the right eighth interspace in the posterior axillary line. The venous pressure June 12, 1944, had dropped to 85 mm. of water and the circulation time with 10 per cent calcium gluconate to 13 seconds, using the right antecubital vein for both studies. Thereafter, his clinical improvement was progressive with no further evidence of accumulation of fluid in either the pleural or pericardial cavities. The basal respiratory and circulatory functions remained stable with the respiratory rate at 20 per minute, the pulse rate 80 to 90 per minute, and the blood pressure varying from 110 to 120 systolic, and from 70 to 80 diastolic. The temperature returned to normal. Repeated x ray and fluoroscopy examinations showed the foreign body always to move synchronously

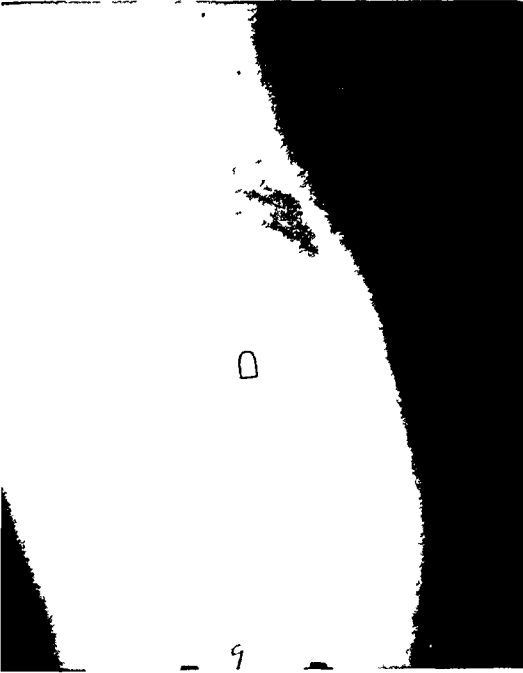


Fig. 9.



Fig. 10.



Fig. 11.

Figs 9 and 10 (Case 2).—Roentgenograms. Aug. 1, 1944, show the final fixed resting position of the bullet along the posterior inferior portion of the left ventricle.

Fig. 11 (Case 2).—Roentgenogram, Sept. 13, 1944, shows the return of the cardiac shadow to normal size and configuration. Bullet removed Aug. 2, 1944.

with the heartbeat and to change position frequently within the pericardial sac, lying first in close proximity to the left ventricle (Fig. 6) then along the right border of the heart (Fig. 8), and finally coming to rest in a fixed position along the posterior inferior portion of the left ventricle (Figs. 9 and 10). The heart shadow remained slightly wider than normal; the right pleural cavity was free of fluid.

Frequently repeated electrocardiographic tracings made after admission to the hospital (Fig. 12) showed the following series of changes. The original tracing of June 7, 1944 (Fig. 12 A) made prior to the pericardicentesis showed a low voltage of the QRS complexes (below 5 mm.) in the limb leads, low T waves in Leads 2 and 4, inverted T waves in Lead 3, and slightly elevated S-T segments in Leads 1, 2, and 4. Following the aspiration of the pericardial cavity, the QRS voltage in the limb leads increased in amplitude and the S-T segments became isoelectric (Fig. 12 B) but the tracings remained stable in other respects. On June 24, 1944 (Fig. 12 C), the T wave in Lead 1 was low and Lead 2 became inverted with the S-T segment, rounded and upwardly convex. After this change the tracings remained essentially stable (Fig. 12 D) until July 24, 1944 (Fig. 12 E), when the T waves in Leads 1, 2, and 4 became upright.

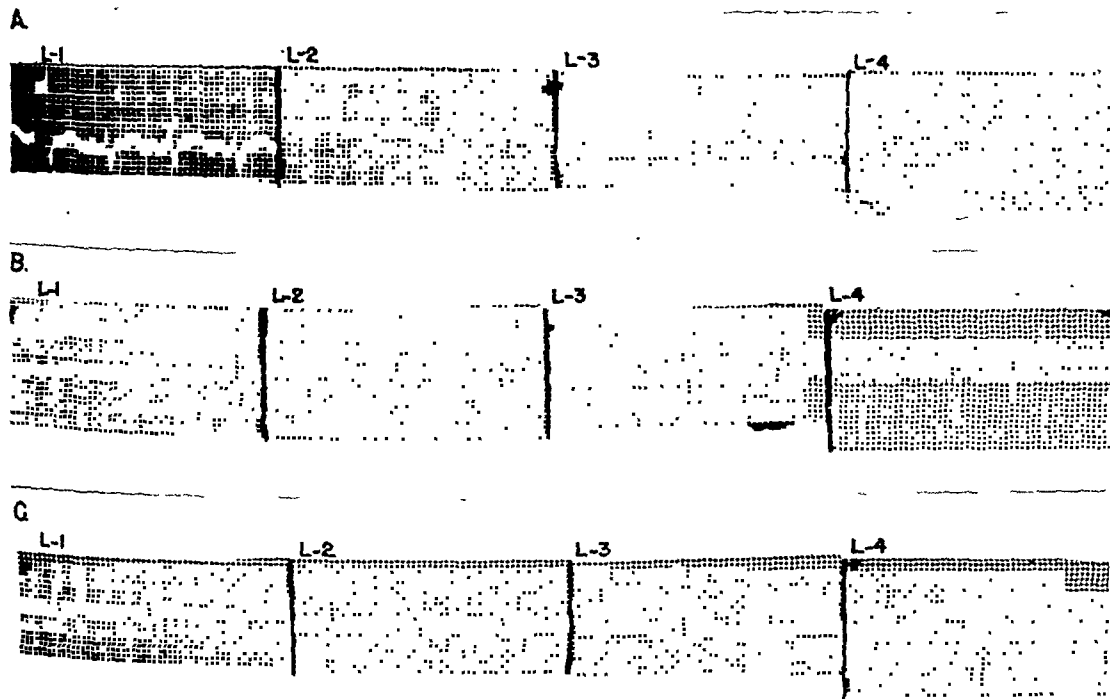


Fig. 12 A-C.—A, June 7, 1944. Rate: Auricular, 120 per minute; ventricular, 120 per minute. P-R interval: 0.16 second; rhythm, normal. P waves: Isoelectric in L_a. QRS complexes: 0.08 per second; low in all limb leads (less than 5 mm.). Prominent and slurred S₁. T waves: T₂₋₄ are low; T₃ inverted; S-T₁₋₂₋₄ show a slight elevation of from 0.5 to 1.0 mm. in most complexes.

B, June 19, 1944. Rate: Auricular, 90 per minute; ventricular, 90 per minute. P-R interval: 0.16 second; rhythm, normal. QRS complexes: 0.08 per second; R₁ = 3 mm. S₁ = 4 mm.; deep S₂; voltage normal. T waves: T₁₋₂₋₄ low; T₃ diphasic.

C, June 24, 1944. Rate: Auricular, 90 per minute; ventricular, 90 per minute. P-R interval: 0.16 second; rhythm, normal. QRS complexes: 0.08 to 0.10 per second, prominent S₁ and S₂; slurred S₁ and R₃; voltage normal. T waves: Low T₁₋₄; late inversion of T₂ with S-T₂ rounded and upwardly convex; T₃ inverted.

June 23, 1944, he was allowed up in a wheel chair and several days later, up and around the ward. As his activities were gradually extended, he became aware of a persistent dull aching pain extending from under the lower portion of the sternum out to the apical area, but not extending up into the shoulder region or down the left arm. This pain was accentuated by exertion and severe discomfort was experienced on walking up one flight of stairs. During the next five weeks he was observed as an ambulatory patient and allowed to walk freely about the ward and hospital area, but he continued to suffer substernal pain on mild exertion. The resting pulse rate remained rapid 90 to 100 per minute and increased to 120 per minute after he climbed one flight of stairs.

In view of the annoying character of the substernal pain, persistent tachycardia, poor exercise tolerance, and size of the foreign body, it was decided that surgical removal was indicated.

Under endotracheal nitrous oxide, oxygen and ether anesthesia, Aug. 2, 1944, a left parasternal incision for an extrapleural approach was made along the sternal margin from the second interspace to the sixth rib and then along the upper border of the sixth rib to the nipple line. The skin-fascia-muscle flap was turned up to expose the fourth and fifth costal cartilages and the anterior ends of the corresponding ribs. The fourth and fifth costal cartilages and 3 cm. of the corresponding ribs were resected subperichondrally and subperiosteally. The posterior perichondrium of each cartilage and the fourth intercostal bundle were divided near the sternum and retracted to the left exposing the internal mammary vessels, which were doubly ligated with No. 1 chromic catgut and divided. The loose prepericardial tissue was incised near the sternal border and carefully stripped to the left with the pleura. The pericardium was incised adequately, great care being taken not to injure the heart which was adherent anteriorly. There were extensive, soft, friable adhesions between

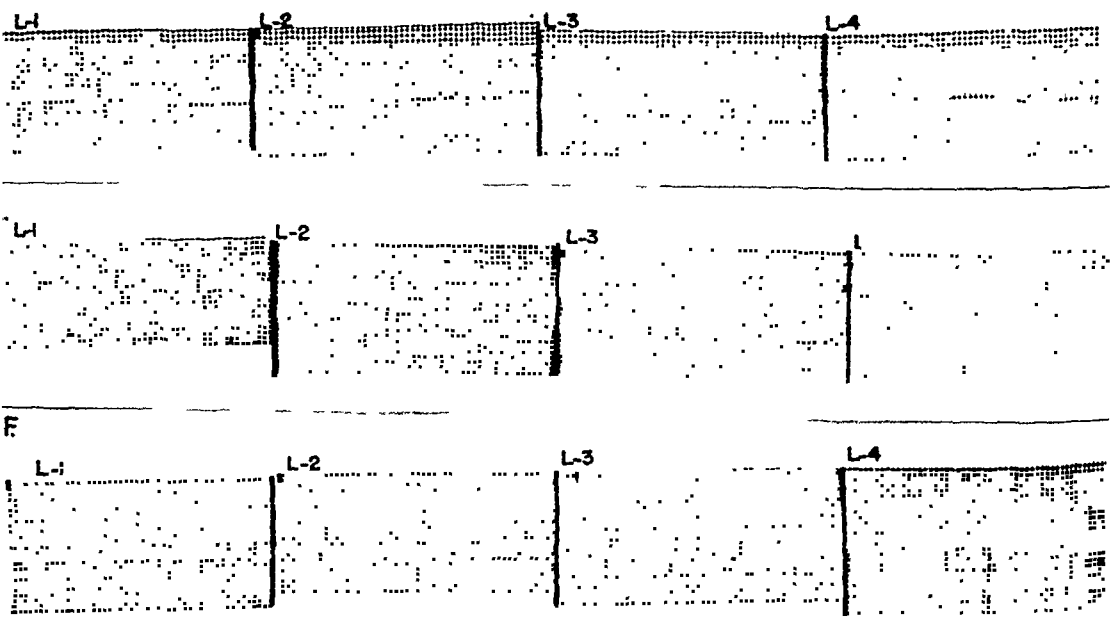


Fig. 12 D-F.—D, July 6, 1944. Rate: Auricular, 100 per minute; ventricular, 100 per minute. P-R interval: 0.12 second, rhythm, normal. QRS complexes: 0.10 second, deep and slurred S_1 ; deep S_2 ; T waves: T_2 inverted; T_1 low.

E, July 23, 1944. Rate: Auricular 100 per minute; ventricular, 100 per minute. P-R interval: 0.14 second; rhythm, normal. QRS complexes: 0.10 second; diphasic QRS 1 with slurred S_1 ; prominent S_2 ; T waves: T_2 inverted. Comment: T_1 are now upright, all S-T segments are isoelectric, and the QRS voltage is normal.

F, Aug. 7, 1944. Rate: Auricular, 130 per minute; ventricular, 130 per minute. P-R interval: 0.12; rhythm sinus tachycardia. QRS complexes: 0.08 to 0.10 second, diphasic QRS 1 with slurred S_1 . T waves: Low T_1 ; T_2 inverted. Comment: Tracing taken on the fifth postoperative day.

the epicardium and pericardium which were gently separated with the finger. The foreign body was located posterior to the left ventricle and was bound by very dense adhesions in this area to the epicardium and pericardium, which were freed with great difficulty. The bullet was then removed without injury to the ventricular wall or pericardium. The pericardial sac was flushed with warm normal saline solution, and 50,000 units of penicillin in 40 c.c. of isotonic saline solution were left in the pericardial sac, which was loosely approximated with interrupted No. 0 chromic catgut sutures. The chest wall was closed in layers, approximating the divided posterior perichondrium with No. 0 chromic catgut, the pectoral sheath with interrupted No. 1 chromic catgut, the subcutaneous tissue with fine catgut, and black silk was used for closure of the skin.

The patient's postoperative course was satisfactory and uneventful without cardiac or pulmonary complications. On the fourteenth postoperative day he was allowed up in the wheel chair and on the sixteenth day up and about the ward. Two months after operation he still described slight precordial discomfort and slight dyspnea on walking up one flight of stairs but this was less severe than that which he experienced prior to operation. He was able to sleep comfortably flat in bed.

Postoperative x-ray studies, Aug. 22, 1944, showed a slight prominence of the left auricular and left ventricular regions with good pulsation of all borders of the heart and the

foreign body previously noted in the lower portion of the cardiac shadow now absent. A teleroentgenogram (Fig. 11), Sept. 13, 1944, showed the transverse diameter of the heart to be 14.1 cm., the transverse diameter of the thorax 34.1 cm., and the cardiothoracic ratio 41 per cent. The heart shadow had changed in configuration since the examination, Aug. 22, 1944, in that the convexity of the left border was not as marked at this time and was tending to assume the same configuration as it had before operation. The pulsation of all borders of the heart was normal.

Electrocardiographic tracings made after the operation showed initially a return to an abnormal configuration and, August 7, 1944 (Fig. 12 *F*), the T waves in Leads 1 and 4 were low or isoelectric. Four days later, Aug. 11, 1944 (Fig. 12 *G*), both T 1 and T 2 became inverted with the S-T segments rounded and upwardly convex. In Leads 4 and 3 the T waves remained low and inverted respectively. One month later, Sept. 11, 1944, the electrocardiographic tracing showed a striking improvement (Fig. 12 *H*) with the T waves in Leads 1, 2, and 4 upright and of normal voltage. The QRS complex in Lead 1 showed an increase in the depth of the S and a decrease in the amplitude of the R waves. A final tracing made Sept. 19, 1944 (Fig. 12 *I*), showed no change and it was interpreted as being normal except for a tendency to a right axis deviation.

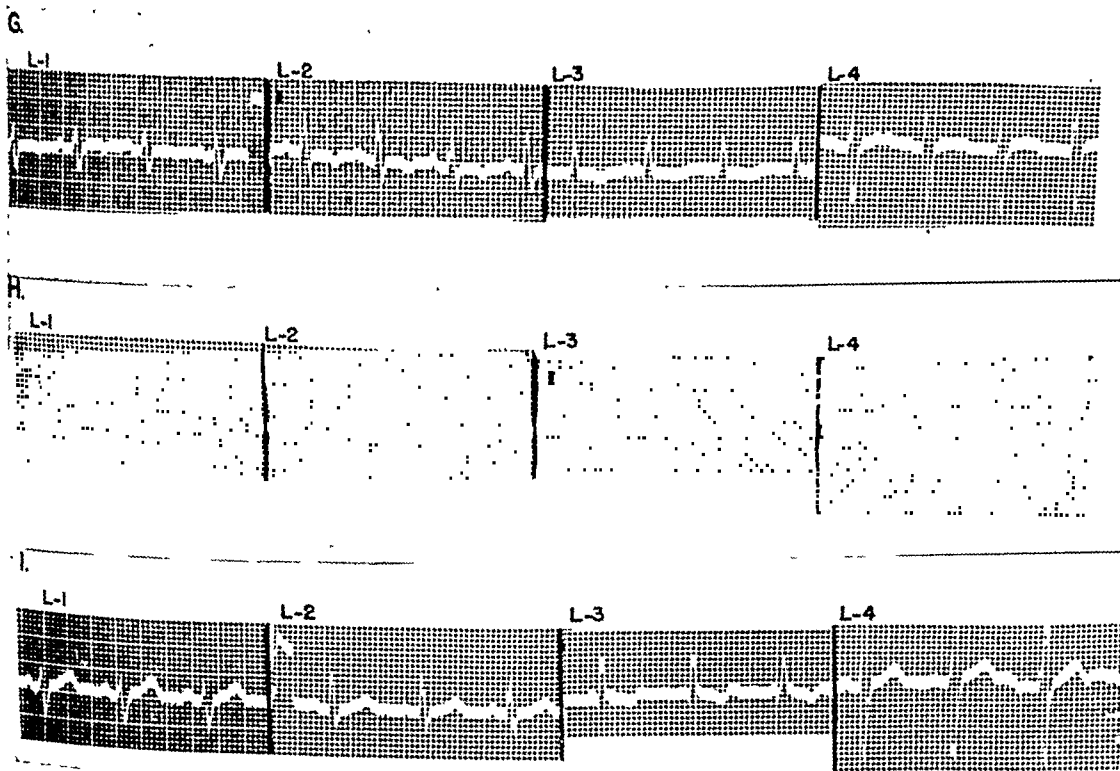


Fig. 12 *G-I*.—*G*, Aug. 11, 1944. Rate: Auricular, 110/120 per minute; ventricular, 110/120 per minute. P-R interval: 0.14 second; rhythm, normal; QRS complexes: 0.08 to 0.10 second; diphasic QRS 1; deep S_2 . T waves: T_{1-2-4} inverted; T_3 low.
H, Sept. 11, 1944. Rate: Auricular, 80 per minute; ventricular, 80 per minute. P-R interval: 0.14 second; rhythm, normal. QRS complexes: 0.10 second; QRS 1 diphasic; S_2 prominent. T waves: T_{1-2-4} upright; T_3 inverted; S-T 4 elevated 1.5 to 2.0 mm.
I, Sept. 19, 1944. Rate: Auricular, 100 per minute; ventricular, 100 per minute. P-R interval: 0.14 second; rhythm, normal. QRS complexes: 0.08 to 0.10 second, QRS 1 inverted; S_2 prominent. T waves: T_3 diphasic; T_{1-2-4} upright.

Examination, Sept. 20, 1944, one week prior to evacuation showed the chest wall to be firm and without defect or weakness at the operative site. The heart tones were normal in quality and there was no evidence of cardiac enlargement. The resting pulse rate was 88 per minute, after exercise 116 per minute, and two minutes after exercise 92 per minute. The blood pressure was 120/65. There was no neck vein distention, the liver was not enlarged, and there was no ankle edema.

COMMENT

It is not our intention to recommend, from the experience with these two cases and the one previously reported by us,¹ that all foreign bodies of the

pericardium should be treated surgically, but it is our desire to call attention to certain aspects of a problem that at present lacks a positive plan of management.

In viewing the available literature²⁻⁴ we are unable to find any clear or definite opinion as to the treatment of patients in this type of case as a group. For the most part the question of surgical intervention lies with the clinical appraisal of each individual case by both internist and surgeon. The patient's symptoms, the objective evidence of pericardial or myocardial changes, and the possibility of future complications are to be balanced against the operative risk. Each of these points of evaluation are at present subject to wide variations in interpretation, and clear, concise discussion of the symptoms, the signs, the pathology encountered, and the possible complications is lacking in most reports.

Pain of a dull aching character occupying the low substernal and precordial areas, increased by exertion but without a tendency to radiate to the neck or down the arms was an outstanding complaint of the patient in Case 2 of this report and also in the one previously reported.¹ In the latter this symptom existed over a period of five months after the injury without the patient being aware that the foreign body was present and was of such a severe and persistent character as to necessitate his being placed on light duty. Even in this capacity he reported his complaint frequently to his medical officer who referred him again to the hospital. Following the surgical removal of the foreign body there was complete relief of pain. In Case 2 of this report the patient had distinct improvement of the pain after operation. In Case 1 the patient did not complain of precordial pain either before or after operation but his reaction to exertion could not be evaluated completely due to the fact that he remained in bed throughout the period of preoperative observation.

Another symptom less definite in nature but existing, nevertheless, in each patient was the anxiety frequently seen and so often commented upon, resulting from the presence of an unremoved foreign body, which is especially marked when vital areas are involved. Each of these men expressed a desire to have the foreign body removed, offered no objection to surgical intervention even though made well aware of the serious nature of the operation, and were most gratified after its successful completion.

The presence of extensive and dense fibrosis within the pericardium has been an outstanding finding in each case and probably is the underlying basis for the subjective complaints and the abnormal objective findings noted. As a result of this observation and especially as a result of our experience with one patient (Case 2), we feel that the optimum time for surgical removal is as soon as the circulatory function becomes stable and the patient's general condition permits. In this case, during the early period of observation, the foreign body was shown to be freely movable and readily accessible within the pericardial sac. Later it became fixed by dense adhesions on the postero-inferior surface of the left ventricle, thereby increasing the technical difficulty and hazard of the operation.

There were abnormal electrocardiographic findings in the case previously reported¹ and in each of the cases of this report. In the former these were interpreted as indicating myocardial damage because of the depth of the inversion of the T waves in Lead 4 and the failure of the patient to show improvement in the seven weeks of observation following operation. In Cases 1 and 2 of this report the electrocardiographic changes were thought to be due to pericardial damage. In both instances the electrocardiogram showed a return to a normal

configuration following the operation. In Case 2 there was an initial improvement in the electrocardiographic pattern prior to operation followed by a temporary return to an abnormal configuration immediately following the surgical removal, in the course of which many adhesions between the epicardium and pericardium were freed.

In addition to the immediate consequences of a foreign body within the pericardium, subsequent developments of a serious nature may result. There is always the danger of infection arising at the location of any foreign body, particularly when organic material, such as clothing, may likely be present as is often the case with penetrating shell fragment and bullet wounds. The adjacent vital structures such as the heart chambers or the great vessels may be eroded or penetrated, with serious or disastrous results.

SUMMARY

1. Two cases of foreign bodies within the pericardium successfully removed are reported in addition to a previously reported case.
2. These cases are being reported because the present literature and available information on the management of such cases is indefinite and indecisive and the problem deserves further study.
3. Each patient showed extensive and dense adhesions between the epicardium and pericardium and around the foreign body which is thought to be responsible for the symptomatology and abnormal objective findings encountered.
4. Surgical removal as soon as the patient's condition warrants is advisable before the foreign body becomes encased in dense adhesions or fixed in an inaccessible area.

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A ROUTINE FOR EARLY SKIN GRAFTING OF DEEP BURNS

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THIS paper presents the experience in the treatment of a group of 154 patients with burns in an overseas U. S. Army General Hospital during a fourteen-month period in Italy. Forty-two, or 27.2 per cent, required grafting as compared with 54 per cent of a group of 78 burn injuries previously reported,¹ the great difference being due to the position occupied by the hospital in the chain of evacuation during the two periods. In a number of instances the burns were associated, in addition, with nerve, bone, and soft part injuries, since 33 per cent of the patients had been wounded in action. We have been interested primarily in the late management of deep burns, since a majority of this group received the initial treatment in other medical installations and were transferred to this hospital from a few days to weeks after the injury. Control of infection is of paramount importance at this time if prompt healing, with early and successful grafting when indicated, is to be accomplished.

Infection, besides jeopardizing the life of the patient, complicates the successful treatment of burns in the following ways: (1) the healing of second degree burns is delayed; (2) deep second degree burns with sufficient viable epithelium for complete coverage may be converted into third degree burns; (3) in third degree burns deeper destruction of tissue occurs with increase in scar tissue formation; (4) grafting may have to be delayed unnecessarily and may even be unsuccessful with the formation of more scar tissue and contractures; and (5) even after the successful take of grafts, furuncles and pustular infection delays the healing of small uncovered "inbetween" areas and destroys portions of viable grafts days or weeks later. The problem, therefore, in burn therapy after shock has been overcome is to control infection and obtain a closed wound as rapidly as possible either by the healing of undestroyed epithelium or by skin grafting.

Penicillin has been used in the primary treatment of burns in this theater since June, 1944. It is given intramuscularly in doses of 25,000 units every three hours. Infection is controlled in the majority of cases, provided the primary dressing is left undisturbed for from twelve to fourteen days. It is our impression that oral sulfadiazine is just as dependable as penicillin during this stage of the treatment. Any drug therapy is only an adjunct to good surgical management and much of the credit for the control of infection must be given to the simple surface treatment used by the U. S. Army. This was originally described by Allen and Koch² and briefly consists of (1) meticulous cleansing of the burned surface,* and (2) a resilient pressure dressing with fine mesh gauze impregnated with petrolatum or boric acid ointment next to the burned surface; this should not be changed for twelve to fourteen days. Care is taken to splint adjacent joints, and, in the case of extremities, to see that the pressure dressings begin at the toes or finger tips and extend well above the burned area. Elevation of temperature occurs when this routine is used, but only on rare occasions is it necessary to change the primary dressing any earlier than

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*Minimal débridement is used in the modified routine of the Army.

twelve to fourteen days for the purpose of inspection. All dressings are done with strict surgical technique under an anesthetic in the operating room if the burns are at all extensive. A majority of second degree burns are found healed when the primary dressing is removed, and there is only minimal contamination or infection in the case of deep burns. All loose, dead skin and the tops of unbroken blisters are removed in unhealed second degree burns and a second petrolatum gauze dressing applied, leaving this undisturbed for another ten or fourteen days. Healing is complete in the majority of the remaining patients when this second dressing is removed, except when there are areas of full skin destruction present which had not been previously recognized.

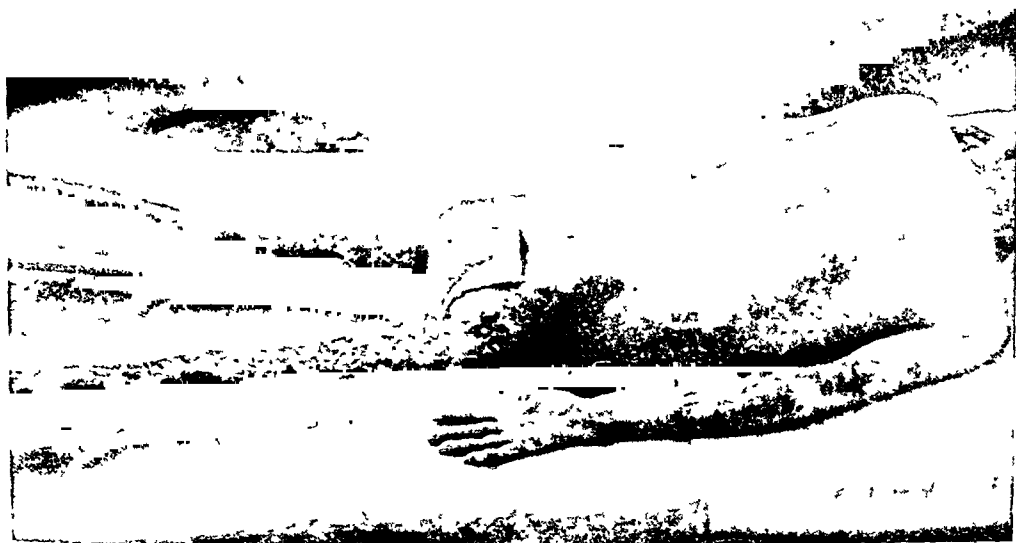


Fig. 1.—Case 5 (see Table I). Photograph taken twenty-four days after injury showing burns healed. Area of full-thickness burn measured 2,100 sq. cm. and had to be removed in three stages. Grafting was done in one stage five days after removal of last slough and twenty-five days after the burn was incurred.

The recognition of full-thickness burned skin and its prompt removal is necessary if grafting is to be done early. The identification of nonviable skin by means of sodium fluorescein³ and the excision of such areas followed by immediate grafting,⁴ either when the burn is first seen or at the time the first or second dressing is done, has been suggested. In principle, primary excision is ideal but practically there are several disadvantages. Fluorescein has not been available through Army channels and so we have had no experience in the use of it. First, the difficulty of otherwise recognizing the area of complete skin destruction and, second, the extensiveness of the area to be excised in an acutely ill patient usually preclude such early removal. Slough has been partially excised at the time of the first dressing, but there are limitations to this. Even at this time it is difficult to tell the limits of full-thickness burns and it is felt that viable epithelium would be sacrificed if complete excision is always attempted in extensive burns. Many times the slough is dry and its removal is so difficult and time consuming that even with two operators working, it must be done in stages. The practice is to excise all or as much demarcated slough as possible at the time of the first change of dressing and thereafter at three- or four-day intervals until all of it is removed. An illustrative example is Case 5 (Fig. 1) in our series, in which there was 2,100 sq. cm. of full-thickness burned skin, the removal of which required four trips to the operating room at three-day intervals.

The poor condition of most of the patients in this series along with the length of time consumed in removing slough contraindicated immediate grafting but a routine was adopted which works satisfactorily. At one time normal saline solution or azocholoramid in saline wet dressings was used to hasten the separation of slough and for the final preparation of the granulating wound for grafting. Moisture often seemed to enhance the growth of *Bacillus pyocyaneus*, proteus, and other contaminants and also macerated the surrounding skin edges. It has been felt by Cope⁵ and others that this macerated skin was a good culture medium for any bacteria present. The frequent changes necessary with a wet dressing also afford an excellent opportunity for the recontamination of the wound by a break in aseptic technique or by air-borne infection. It was found that penicillin given parenterally did not control infection when this routine was used and grafting frequently had to be delayed. In June, 1944, at the suggestion of Lyons,⁶ we began applying dry, fine mesh gauze pressure dressings after the last slough had been removed and continued or began intramuscular penicillin in doses of 25,000 units every three hours. The dressing is left undisturbed until the patient is taken to the operating room four to six days later for grafting. The additional time is used to bring the blood values to normal with transfusions of blood or plasma as indicated.

The following advantages result from this routine. First, infection is controlled. Fifteen patients were treated in this fashion and in every instance grafting was done four to six days later. The maximum elapsed time between the injury and primary grafting was thirty-two days with an average of 25.5 days for the group (Table I), while in a group of patients prepared with wet dressings the average elapsed time before grafting was 41 days (Table III). The remaining patients grafted reached our installation in from 30 to 60 days after incurring the burn injury and usually had been treated with saline solution wet dressings. On admission all slough, when present, is removed, the skin edges cleaned with white soap and water, and a dry, fine mesh gauze dressing applied. Grafting was possible four to six days later in every instance regardless of the amount of contamination or infection present on admission (Table II). Second, grafting is more successful since infection is controlled and also because this routine makes earlier grafting possible. We do not have figures on our cases to demonstrate this but Hirshfield and others⁷ reported a greater percentage of take of grafts when penicillin was used. Actual determination of the percentage of take of grafts in the case of burn wounds is difficult to appraise because many times grafts are placed over areas containing epithelium. The earlier grafting is done the more frequently does this occur but skin is an ideal dressing and the excess can easily be cut away at subsequent dressings. Third, the patient's discomfort is greatly reduced by this simple routine. Patients have been frequently heard to say "I thought burns were painful but mine have not been." Fourth, scar tissue and resulting contractures are diminished by early grafting. Fifth, the amount of dressings, drugs, and other supplies necessary for treating a burn are reduced, medical personnel are freed for other duties, and many days of hospitalization are saved.

When this technique is used, the burn wounds are found covered with healthy granulations at the time of grafting, although four or five days previously the dissection was carried down to subcutaneous tissue. These granulations are not disturbed. However, in the patients admitted late, it is often necessary to cut the exuberant granulation away. Split-skin grafts are always used, and are removed either with the Padgett dermatome or with a modifica-

TABLE I. PATIENTS PREPARED FOR GRAFTING WITH SKIN

CASE NO.	AGENT	LOCATION	AREA GRAFTED (SQ. CM.)	NO. DAYS AFTER INJURY		DAYS ELAPSING BETWEEN INJURY AND REMOVAL OF ALL SLOUGH	DAYS ELAPSING BETWEEN INJURY AND PRIMARY GRAFTING	DAYS ELAPSING BETWEEN PRIMARY AND SUBSEQUENT GRAFTING	FINAL DISPOSITION AND CONDITION
				PATIENT WAS RE-CEIVED AT GENERAL HOSPITAL	INJURY				
1	Thermal, gasoline	Leg	126	1		26	32		Discharged from surgical to dental service 84 days after injury healed and ready for duty
2	Thermal, alcohol	Leg	600	7		25	29		To Zone of Interior 111 days after injury healed but requiring conditioning and physiotherapy
3	Thermal, gasoline	Thigh, leg	725	2		18	22		Discharged from surgical to medical service with hepatitis 64 days after injury healed; to duty after 124 days
4	Thermal, gasoline	Forearm	300	9		24	29		To Zone of Interior 80 days after injury with peroneal nerve paralysis, but healed
5	Thermal, gasoline (W.I.A.*)	Thigh, leg, forearm	2,100	8		19	24	8	To Zone of Interior 64 days after injury healed but requiring physiotherapy and conditioning
6	Thermal, bed-clothes from cigarette	Both hands	60	9		19	24		To Zone of Interior 59 days after injury healed but requiring physiotherapy and possible plastic repair
7	Thermal, gasoline (W.I.A.)	Both hands	79	4		24	29	10	To Zone of Interior 56 days after injury healed but requiring physiotherapy and possible plastic repair
8	Thermal, gasoline	Both arms	478	14		24	30	14	To duty 126 days after injury
9	Thermal, gasoline	Arm	196	4		12	16	12 & 31	To duty 116 days after injury
10	Thermal, gasoline	Popliteal space	250	22		22	27	16	Discharged from surgical to medical service 61 days after injury healed, to duty after 122 days
11	Thermal, bed-clothes from cigarette	Chest, arm	360	20		25	28		To duty 78 days after injury
12	Thermal, gasoline	Both hands	80	0		25	29		To Zone of Interior 76 days after injury healed but requiring physiotherapy and possible plastic repair
13	Thermal, gasoline	Both thighs, lower leg	615	11		20	25	11	Healed 71 days after injury and awaiting conditioning before discharge to duty
14	Thermal, gasoline	Both legs	950	7		21	26	9, 19, & 34	Healed except for small area 72 days after injury and awaiting conditioning before discharge to duty
15	Chemical, phos. (W.I.A.)	Hand	60	3		7	13		Healed 60 days after injury and awaiting conditioning before discharge to duty

TABLE II. PATIENTS RECEIVED AFTER THIRTY DAYS, THEN PREPARED FOR GRAFTING WITH DRY DRESSINGS AND PENICILLIN

CASE NO.	AGENT	LOCATION	GRAFTED (SQ. CM.)	NO. DAYS AFTER INJURY		DAYS ELAPSING BETWEEN INJURY AND REMOVAL OF ALL SLOUGH	DAYS ELAPSING BETWEEN PRIMARY GRAFTING	DAYS ELAPSING BETWEEN PRIMARY AND SUBSEQUENT GRAFTING	FINAL DISPOSITION AND CONDITION
				PATIENT WAS RECEIVED AT GENERAL HOSPITAL					
16	Thermal, gasoline	(1) Lower left leg	750	43	No record		(1) 45 (2) 50	15	To Zone of Interior 125 days after injury healed but requiring physiotherapy and conditioning
17	Thermal, gasoline	(2) Right thigh	204	60	No record		64	8	To Zone of Interior 144 days with small area unhealed
18	Thermal, gasoline	Both legs	1,300	30	30		35	10	To Zone of Interior 108 days after injury healed but requiring physiotherapy and conditioning
19	Chemical, phosphate (W.I.A.*)	Entire leg	No record	31	No record		34	23, 39	To Zone of Interior 102 days after injury healed but requiring physiotherapy and conditioning
20	Thermal, gasoline	Arm	228	31	No record		36		To Zone of Interior 159 days after injury healed but with unhealed area on donor site
21	Chemical, phosphate	Lower leg	625	38	No record		43	18, 32	Healed 103 days after injury and awaiting conditioning before discharge to duty
22	Thermal, gasoline	Forearm	36	52	No record		55		To duty 98 days after injury healed

*W.I.A., Wounded in action.

tion of the Blair-Brown knife with a roller attachment. When the area to be covered is extensive, the latter method is preferred because the amount of skin necessary can be obtained in a much shorter period of time and it is felt that complete coverage is more desirable at this time than cosmetic appearance. Grafts are not sutured in place except in the case of large dermatome sheets when this is important if stretch of the skin to the original size is to be obtained. It is our experience that grafts become firmly adherent within a few minutes after being placed, because the necessary substances for adherence are present in the wound itself. We have not used plasma and thrombin⁸ but have tried 50 per cent gum acacia solution.⁹ No difference was noted in the take of grafts with or without gum acacia, although pressure dressings were always applied. Plasma and thrombin and gum acacia may provide perfect contact between the graft and the wound so that pressure is not necessary but it is felt



A.

B.

Fig. 2—Case 14 (see Table I). A, Photograph taken in operating room before grafting twenty-six days after burn injury. B, photograph taken sixty-three days after injury, showing burns healed except for several small areas

that a pressure dressing is safer, more comfortable to the patient, and promotes healing by preventing the accumulation of fluids in the tissues. A petrolatum gauze pressure dressing with splinting of the adjacent joints is applied to both the donor and recipient areas, care always being taken to begin the pressure dressing at the toes or fingers. The dressing on the grafted area is removed on the fifth or sixth day after operation when all sutures, if used, are removed and nonviable and overlapping skin cut away. This greatly reduces the chances of serious infection and better assures the continued viability of all skin that has taken. The dressing on the donor site is not changed until the gauze next to the wound becomes loose, which usually happens from fourteen to twenty-one days following the removal of the grafts. Most of the donor sites are healed at this time.

TABLE III. PATIENTS PREPARED FOR GRAFTING WITH WET DRESSINGS

CASE NO.	AGENT	LOCATION	AREA GRAFTED (SQ. CM.)	NO. DAYS AFTER INJURY PATIENT WAS RECEIVED AT GENERAL HOSPITAL	DAYS ELAPSING BETWEEN INJURY AND REMOVAL OF ALL SLOUGH	DAYS ELAPSING BETWEEN INJURY AND PRIMARY GRAFTING	DAYS ELAPSING BETWEEN PRIMARY AND SUBSEQUENT GRAFTING	FINAL DISPOSITION AND CONDITION
23	Thermal, gasoline	Lower leg	16	43	No record	60	87	To limited duty 122 days after injury
24	Thermal, water	Lower leg	4	8	No record	34		To duty 87 days after injury
25	Thermal, gasoline	Lower leg	120	10	26	44		To duty 99 days after injury
26	Thermal, gasoline	Lower leg	144	6	16	34		To duty 95 days after injury; discharge delayed by recurrent malaria
27	Thermal, gasoline	(1) Both fore-arms, both hands	No record	28	No record	(1) 45	25	To Zone of Interior 99 days after injury healed but requiring physiotherapy and possible plastic repair
28	Chemical, caustic soda	(2) Both legs	443	0	No record	(2) 56		To duty 58 days after injury healed
29	Chemical, caustic soda	Face	42.5			18		
30	Thermal, coal fire	Face	2	0	No record	18		To duty 37 days after injury healed
31	Thermal, water	(1) Both arms	342.5	0		(1) 28	50, 66	To Zone of Interior 105 days after injury healed but requiring physiotherapy and conditioning
		(2) Rt. leg	630	0	20	(2) 38		To Zone of Interior 120 days, after injury not completely healed; grafting delayed by lobar pneumonia
		(3) Lt. leg	544	0		(3) 52		
		Upper arm	78	6	No record	73		To duty 104 days after injury
32	Thermal, gasoline	Thigh	18	2	No record	79		

33	Thermal, gasoline	Both thighs	84	21	No record	44	10	To duty 171 days after injury healed; grafting delayed by exfoliative dermatitis and toxic psychosis due to sulfonamides. Discharge delayed by hepatitis which developed 99 days after injury
34	Thermal, gasoline (W.I.A.*)	(1) Face (2) Both hands, thigh	40 53	2	No record	(1) 18 (2) 29	22	To Zone of Interior 89 days after injury healed but requiring physiotherapy and conditioning
35	Chemical, phos. (W.I.A.)	(1) Eyelids (2) Both legs	No record 650	1	No record	(1) 30 (2) 65	68	To Zone of Interior 111 days after injury not completely healed
36	Thermal, gasoline (W.I.A.)	Hand	5	5	No record	59		To duty 99 days after injury healed
37	Thermal, gasoline (W.I.A.)	Both fore- arms	80	7	No record	31		To Zone of Interior 75 days after injury with ulna nerve paralysis, but healed
38	Thermal, gasoline (W.I.A.)	Both fore- arms, hands	No record	7	17	30	10	To Zone of Interior 88 days after injury healed but requiring physiotherapy and possible plastic repair
39	Thermal, gasoline	Hand, both legs	784	8	No record	32	21	To Zone of Interior 88 days after injury healed but requiring physiotherapy and conditioning
40	Chemical, battery acid	Chest wall, anterior neck	210	33	No record	58		To Zone of Interior 98 days after injury not completely healed and with contracture of neck
41	Thermal, water	Thigh	35	36	No record	50	57	Discharged to convalescent section 92 days after injury healed; small area 2 cm. in diameter broke down and still confined to hospital
42	Chemical, phos. (W.I.A.)	Thigh	740	13	No record	33		To limited duty 109 days after injury

*W.I.A., Wounded in action.

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THE INTRAHILAR AND RELATED SEGMENTAL ANATOMY OF THE LUNG

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TO WILLIAM EWART, physician and pathologist of the Victorian era, belongs the credit of first displaying in detail "the general arrangement of parts within the lung." Reasoning that without such knowledge there could be no systematic development in the diagnosis and treatment of pulmonary diseases (especially "pulmonary cavities"), he established in 1889 a nomenclature covering even the moderate-sized branches of the bronchial and vascular pulmonary trees. That his system of nomenclature was somewhat ponderous and inconsistent, that he sometimes carried rigid description beyond the limits of usefulness, and that his sketches were not always decipherable does not minimize the fact that he anticipated by nearly one-half a century the needs of modern thoracic surgery and presented with extraordinary accuracy an enormous amount of anatomic detail. Indeed the work is the more remarkable in that the contemporary and subsequent search by anatomists for an ancestral pulmonary pattern, which might have been expected to yield an authentic nomenclature, foundered in 1920 with Huntington's conclusion that the primitive mammalian pattern was neither eparterial nor hyparterial but selective, that is, that the stem bronchus of mammals is plastic, having the potency to develop buds anywhere on its circumference in response to the respiratory needs of the species and the location of the space available for expansion. On this basis the patterns in different species are not expected to be closely homologous (neither are right and left halves in the same species). Accordingly, the problem for the anatomist becomes that which was conceived by Ewart, namely, to describe the parts of the lung topographically, in terms of the prevailing structure to be found in a given species.

The distinctive feature of Ewart's work was his recognition of the fact that "the lung must be divided into yet smaller regions [than the lobes] in order to attain simplicity in description. . . . Thus, in addition to the apex and to the base, to the upper and to the lower axillary regions, we shall have to speak of the

This article is an outgrowth of a surgical staff conference in which the author was asked by Dr. Owen H. Wangenstein to discuss the anatomy of segmental pneumonectomy. Search of the literature having failed to yield any comprehensive figures of dissections of the external and interlobar surfaces of the lung, the author was obliged to make preliminary dissections. The present article is an attempt to remedy that defect in the literature.

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'pectoral,' of the 'cardiac,' of the 'mid-dorsal,' of the 'retrocardiac,' and of other regions. . . . But in doing so we discover that the districts in question are practically identical with the respective territories of the several primary bronchi." Thereupon he proceeded to describe nine "*bronchial distributions*" or "primary bronchi."

Forty-three years later (1932) the bronchoscopists Kramer and Glass arrived at the same conclusion. In order to tell the position of an abscess in the lung they felt it necessary "to establish smaller and more accurate units of localization than the lobe." This unit they called the "*bronchopulmonary segment*." Apparently unaware of Ewart's work, Glass identified eleven segments, the nine of Ewart's with the pectoral and cardiac distributions further subdivided. In addition, Glass pictured for the first time the position of the segments on the surface of the lobes.*

This article stimulated other bronchoscopists to present revised systems of nomenclature, but in 1938 a new direction was given to the movement by Churchill who called attention to the bronchopulmonary segment as a unit of surgical importance in resections of the lung for bronchiectasis. Soon there followed a series of articles by Churchill, Blades, and others dealing with the surgical anatomy of the hilum, including blood vessels as well as bronchi. Important as these studies are they have raised the question as to how a beginner, at least, could adequately identify structures in the hilum† unless he knew more about their peripheral distribution. In short, what is still needed is a series of dissections showing the arrangement of parts within the anterior, the interlobar, and the posterior surfaces of the lung, together with a terminology simple enough to be easily retained. The anatomist would also wish to inquire to what extent the segments may be considered bronchovascular units.

With this object in view I have made complete dissections and sketches of two pairs of lungs. The first set of seven drawings was preliminary; the second was made with a view to publication. In the latter series, the artist, Miss Jean Hirsch, first sketched the contours and surfaces of the lobes life sized; then I dissected the lobes and carefully sketched in an outline of dissected parts; the artist traced these drawings and with the specimen before her, rendered them in depth; last, all tissue was stripped from the bronchial tree and the latter accurately drawn by me (Fig. 1). It was to be expected, of course, that in certain minor respects the anatomy of the specimen chosen for publication would turn out to be atypical, but this merely emphasizes the variations which we have come to learn are as important as the norm. Also, it should be pointed out that since these drawings were made with a view to the needs of anatomists and surgeons, the anterior margins of the upper and middle lobes have been retracted laterally. This distorts the in situ relations so essential to the roentgenologist. But it is maintained that even for the latter the preliminary experience acquired by dissection is requisite to an understanding of lung structure.

GENERAL OBSERVATIONS

I have selected the nomenclature of Jackson and Huber (1943) as the most satisfactory, for two reasons. First, believing that the largest segments into which each lobe divides are those of the greatest clinical importance, they have

*This method of studying surface projections by injecting individual bronchi, and of correlating this information with that obtained from bronchograms and metal casts of the bronchial tree, has been most successfully carried out by the London surgeon Brock (1942 to 1944), a primary objective being to ascertain where on the parietal wall an abscessed segment will present itself for drainage.

†In most texts this word reads *hilus*, but Hyrtl pointed out in 1880 that the latter is "barbarisch."

bronchus of the upper lobe. It has been numbered B^3 instead of B^2 for the reason that neither it nor its artery is seen in an anterior dissection of the upper lobe. Furthermore, its blood supply, A^3 , Plate 5, is frequently unrelated to that of the other bronchi, whereas the arteries accompanying the apical and anterior bronchi have a common hilar stem, A^1 , A^2 , Plate 4. From a practical standpoint, therefore, and considering the vessels as well as the bronchi, it is necessary to number these segments in the order in which they are exposed by dissection or encountered surgically. With this introduction let us consider the general characteristics of the right bronchial tree.

The Bronchi of the Right Upper Lobe.—First, the upper lobe bronchus arises almost at the bifurcation of the trachea (Fig. 1). Therefore, it would be much more difficult to amputate the whole right lung than the left and there would be more likelihood that a bronchial fistula would develop.

The superior lobar bronchus, S (the eparterial bronchus of Aebv), is likewise very short. It branches almost immediately into three stems, the apical, anterior, and posterior segmental bronchi. Ewart stated that B^2 (his "pectoral" distribution) is the first to branch off and that B^1 and B^3 have a common stem (the "axillary-apical" trunk), but this is variable. B^2 and B^3 may arise from a common trunk, as in Fig. 1, or B^1 and B^2 (Broek, 1942); more commonly the three may form a trifurcation. B^1 and B^3 divide in such a way as to constitute a tier of four bronchial planes distributed through the thickness of the apical half of the lobe. The first two planes, B^1a , B^1b , Plate 4, may be seen beneath the anterior surface; the last two, B^3a1 , B^3b1 and B^3a2 , B^3b2 , may be seen deep to the posterior surface of the upper lobe (Plate 5). In some specimens in

EXPLANATION OF PLATES

Plates 1 to 3.—Dissections of anterior, interlobar, and posterior surfaces of left lung of 66-year-old white man ($\times \frac{1}{2}$).

Plates 4 to 7.—Dissections of anterior, upper and lower interlobar, and posterior surfaces of right lung of same subject ($\times \frac{1}{2}$).

Segmental Bronchi (Right Lung)

S , Superior lobar bronchus
 B^1 , Apical
 B^2 , Anterior
 B^3 , Posterior

M , Middle lobar bronchus
 B^4 , Lateral
 B^5 , Medial

I , Inferior lobar bronchus
 B^6 , Superior
 B^7 , Medial basal
 B^8 , Anterior basal
 B^9 , Lateral basal
 B^{10} , Posterior basal

B^* , Subsuperior segmental bronchus (inconstant in presence and position).

Segmental Arteries

A^1 , Apical	} Right upper lobe	A^1 , Apical	} Left upper lobe
A^2 , Anterior		A^2 , Anterior	
A^3 , Posterior		A^3 , Posterior	
A^4 , Lateral	} Middle lobe	A^4 , Superior lingular	} Middle lobe
A^5 , Medial		A^5 , Inferior lingular	

A^6 , Superior	} Lower lobes
A^7 , Medial basal	
A^8 , Anterior basal	
A^9 , Lateral basal	
A^{10} , Posterior basal	

A^* , Subsuperior segmental artery (inconstant in presence and position).

Left Lung

S , Superior lobar bronchus
 U , Upper division
 B^{1+3} , Apical-posterior
 B^2 , Anterior

Li , Lower (lingular) division
 B^4 , Superior (lingular)
 B^5 , Inferior (lingular)

I , Inferior lobar bronchus
 B^6 , Superior
 B^7 and B^8 , Anterior-medial basal
 B^9 , Lateral basal
 B^{10} , Posterior basal

Tributaries of Pulmonary Veins

(Superior pulmonary veins)

V^1 , Apical-anterior	} Right upper lobe	V^{1+3} , Apical-posterior	} Left upper lobe
V^2 , Inferior		V^2 , Anterior lingular	
V^3 , Posterior		V^4 , Superior lingular	
V^4 , Lateral	} Middle lobe	V^5 , Inferior lingular	} Middle lobe
V^5 , Medial			

(Inferior pulmonary veins)

V^6 , Superior	} Right and left lower lobes
V^7 , Medial basal	
V^8 , Anterior basal	
V^9 , Lateral basal	
V^{10} , Posterior basal	

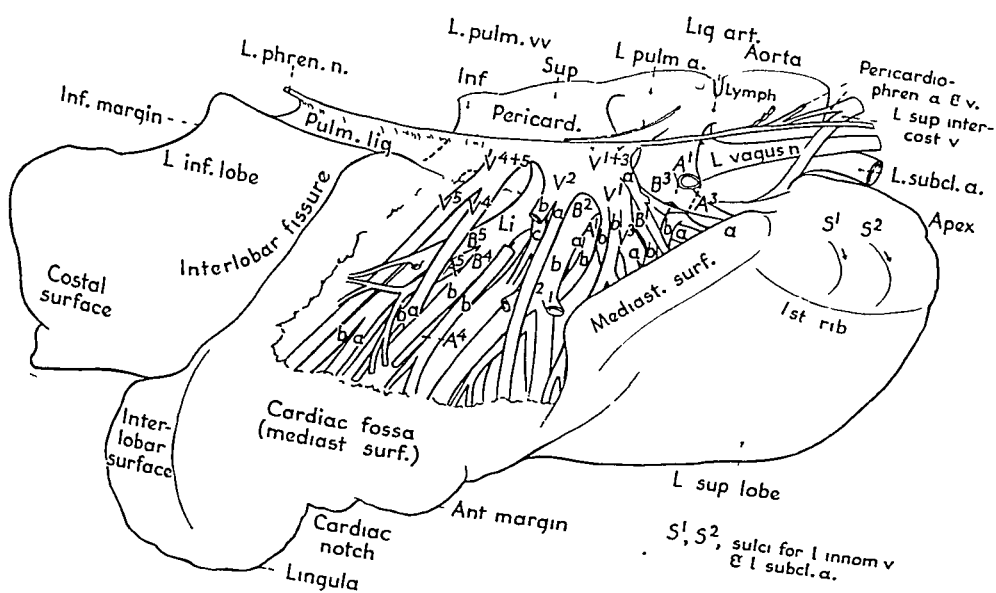
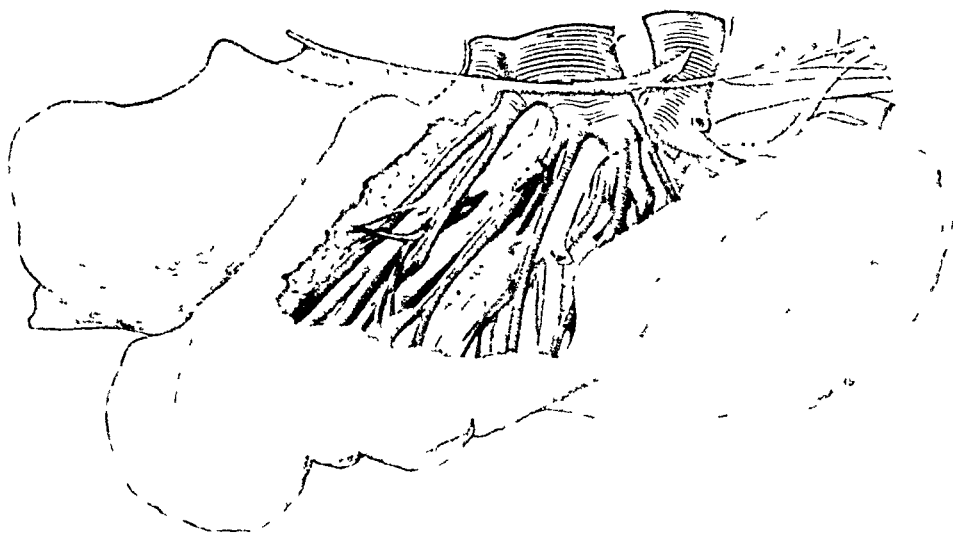


PLATE 1 Left lung, superior lobe, *anterior view*

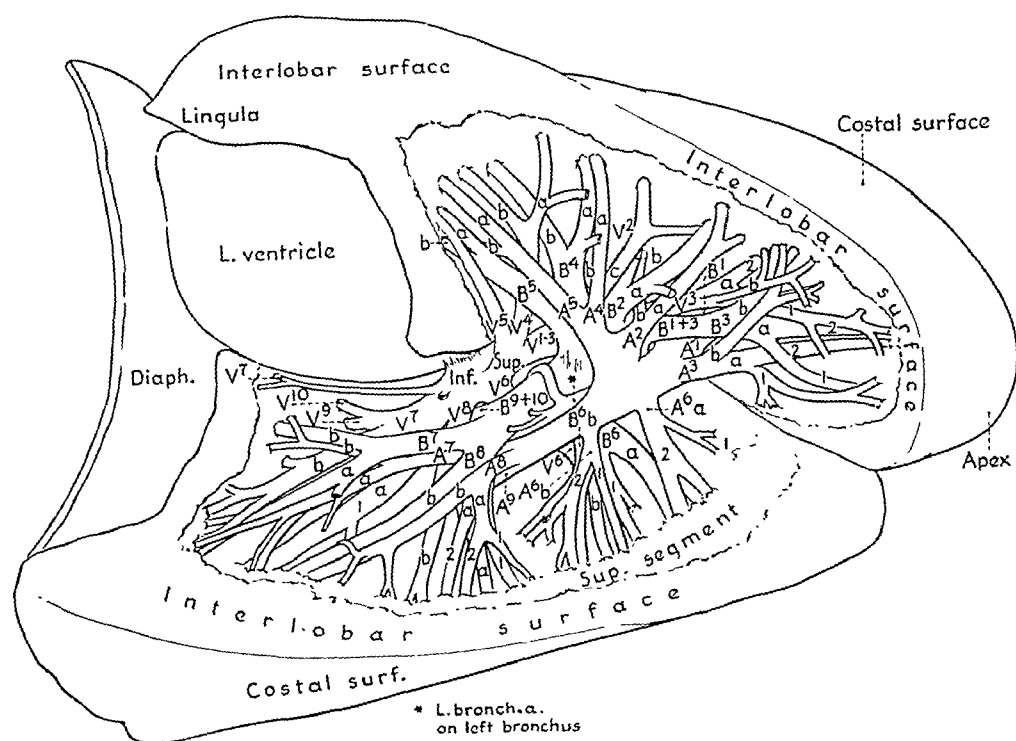
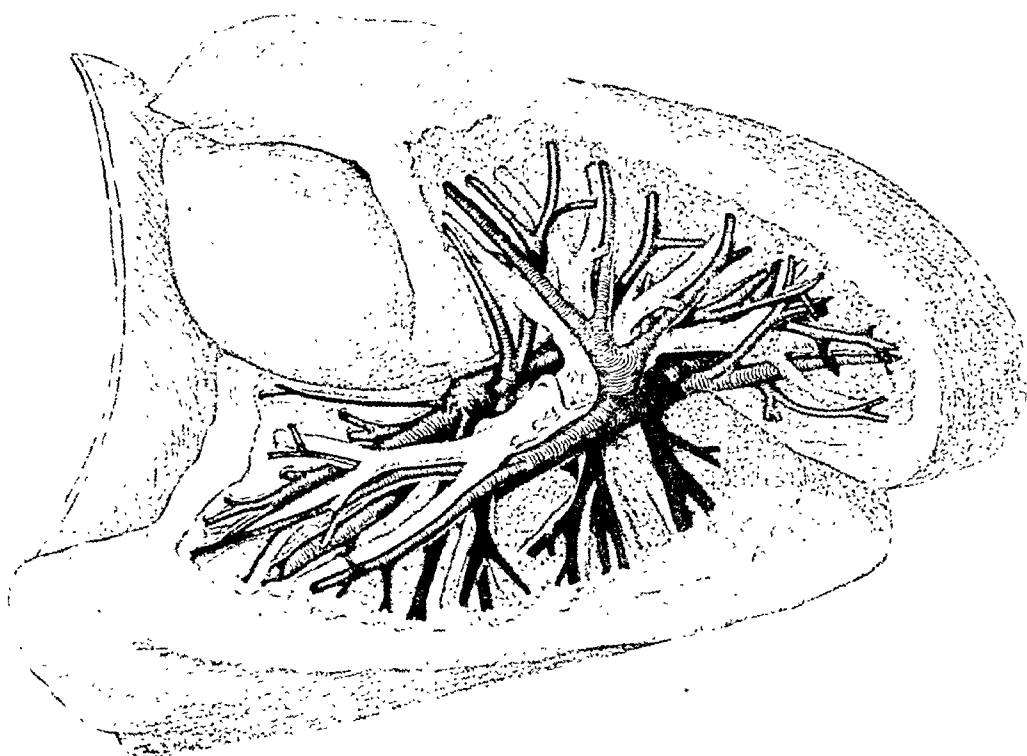


PLATE 2 Left lung, superior lobe *elevated*

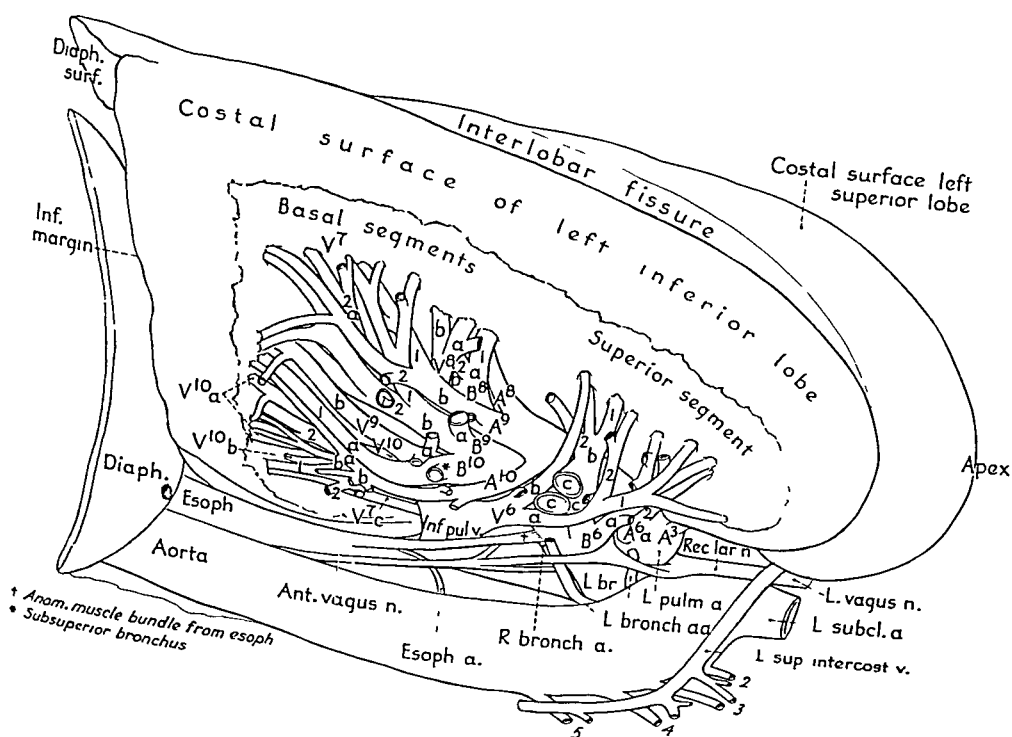
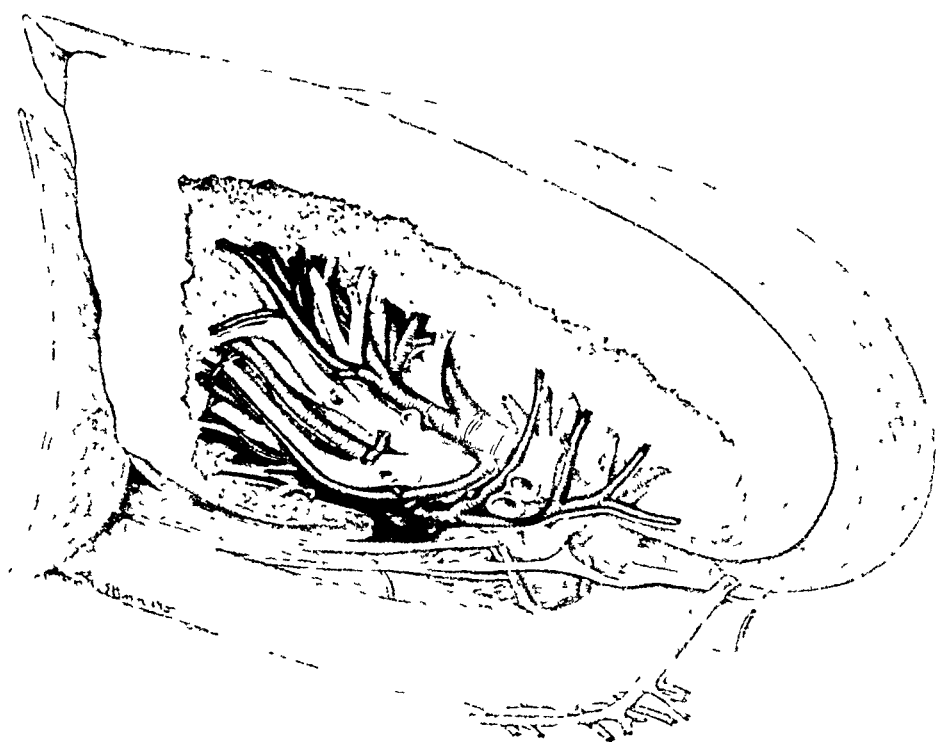
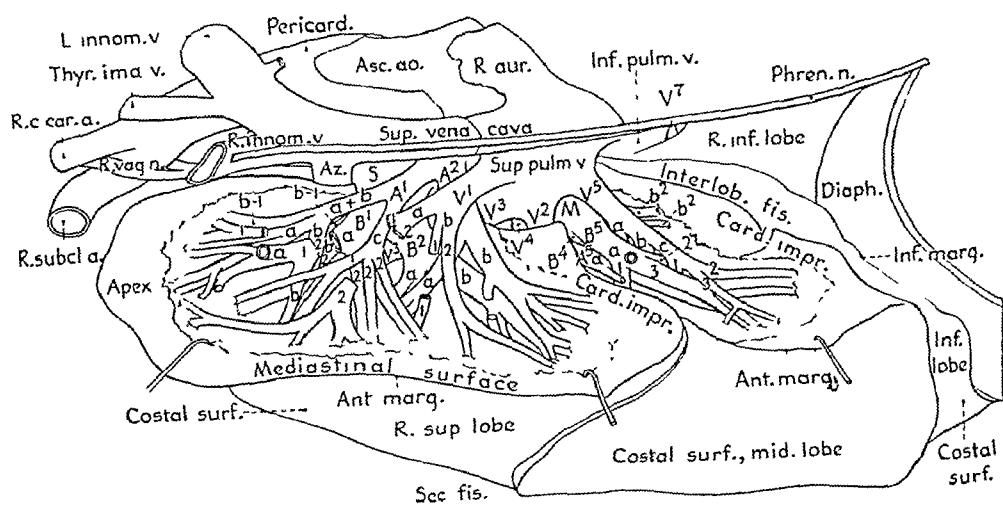


PLATE 3 Left lung, inferior lobe, posterior view



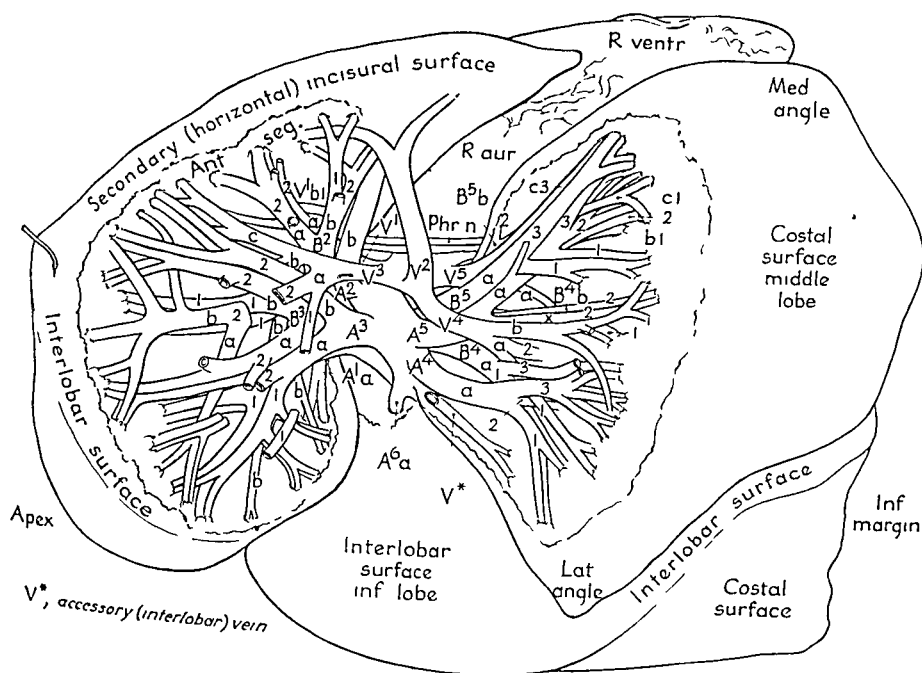
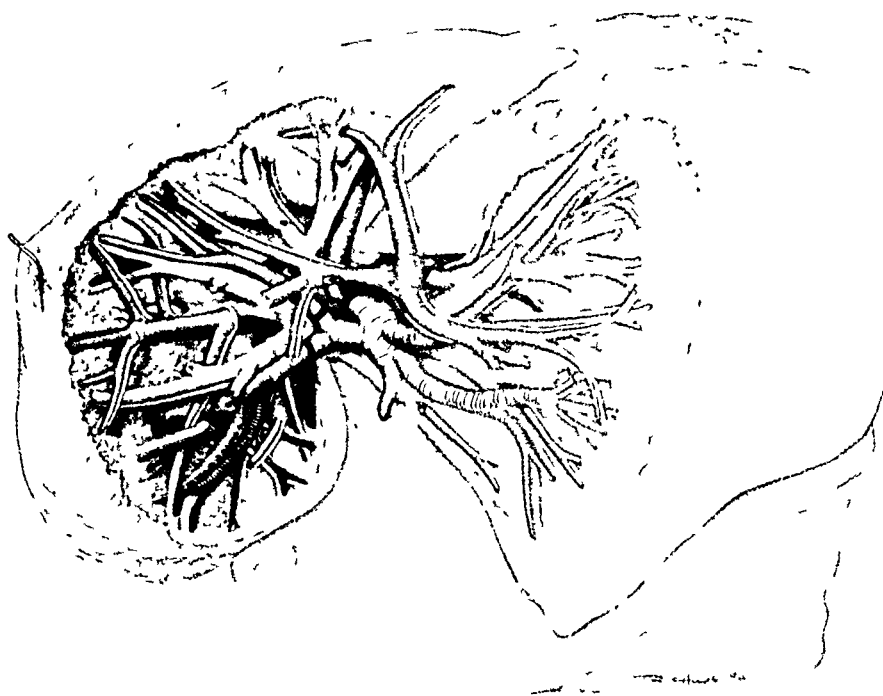


PLATE 5 Right lung, superior lobe *elevated*

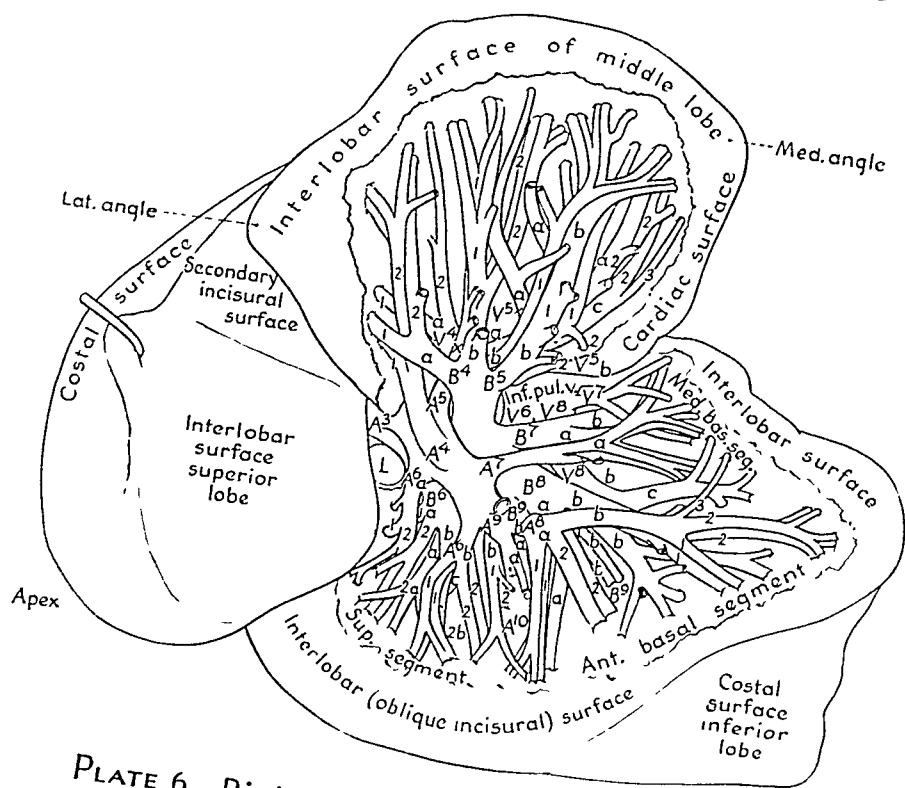


PLATE 6 Right lung, middle lobe elevated

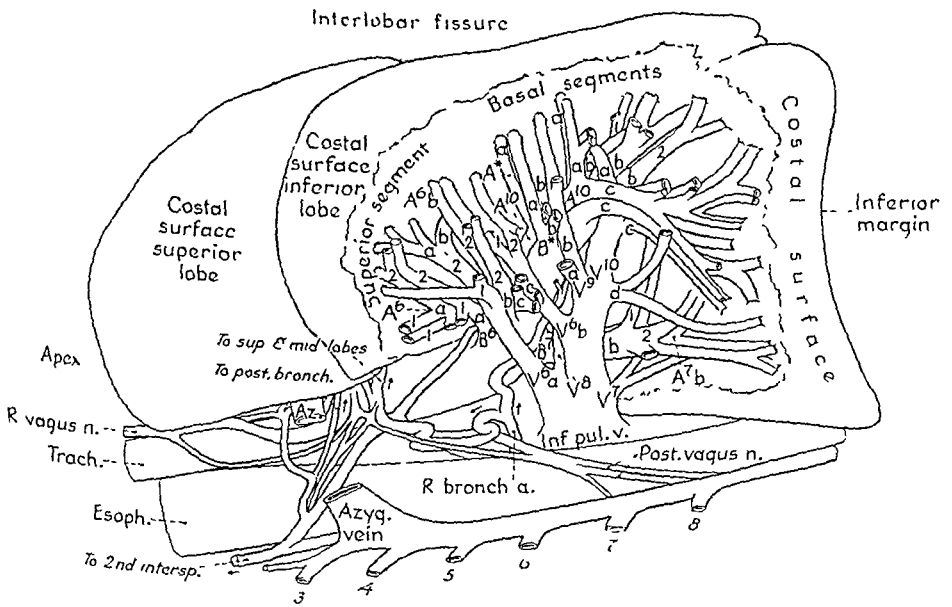
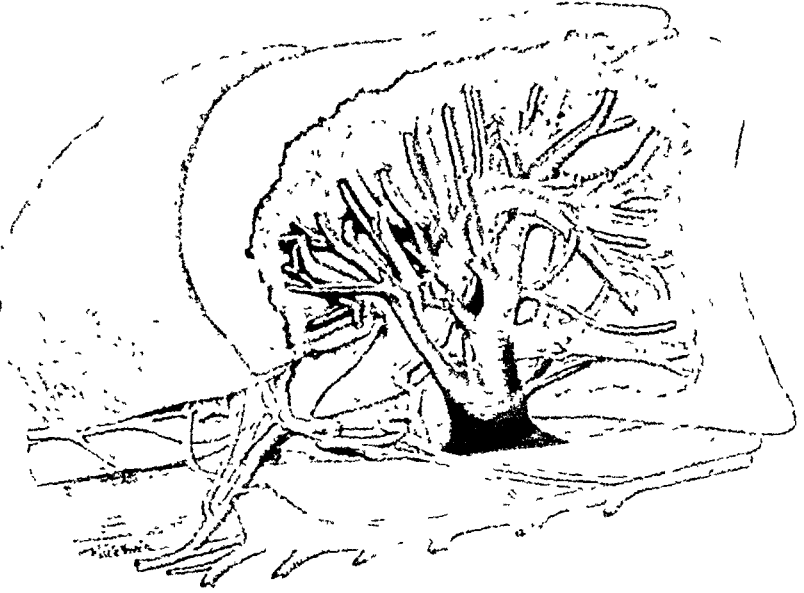


PLATE 7 Right lung, *posterior view*

which the lobe is thinner and the branching more fan shaped there are only two or three tiers.

The apical segmental bronchus, B^1 , divides into an anterior ramus, a , and a posterior ramus, b (the anterior and posterior ascending apical trunks of Ewart). Of significance to the vascular system is the wide angle at which the anterior subramus B^1a2 (the tracheal-apical trunk of Ewart) leaves the main stem, thereby giving to B^1 the appearance of a tripod. As a result, the corresponding artery, A^1 , frequently breaks up into three rami. Regarding the common anomalies, Brock (1944) described several specimens in which a supernumerary apical bronchus arises from the right bronchus or even from the trachea itself. This suggests the pattern found in cattle, pigs, and whales but differs from it in having only one instead of a cluster of branches which are tracheal in origin. Brock also described the varying number of apical rami which supply the lobe that is cut off anomalously by the azygos vein.

The anterior segmental bronchus, B^2 (the pectoral of Ewart), is of special clinical interest. In cases of bronchiectasis where there is little involvement of the rest of the upper lobe, this segment is now sometimes resected by itself (Blades, personal communication). The bronchus divides into a lateral ramus, a , a retreating branch which distributes to the region lying deep to the axilla, and an anterior ramus, b , which descends to the tip of the thin inferior portion of the upper lobe. (Ewart's names for these are the mid-pectoral and sternopectoral bronchi.) Several bronchoscopists (and surgeons) have elevated B^2a and B^2b to the category of segmental bronchi (namely, Kramer and Glass, Churchill and Belsey, Neil and associates, Adams and Davenport). Perhaps this is because these rami occasionally branch directly from the upper lobe bronchus or, perhaps, because Kramer and Glass considered B^2b to be one of the two most common sites of lung abscesses in the upper lobe; the other is B^1 . (Brock, 1942, considered B^2a and B^3 the more common sites.) In any event it seems sufficient to refer to them as the lateral and anterior rami of B^2 .

The posterior segmental bronchus, B^3 , divides into a posterior ramus, a , and a lateral ramus, b , Plate 5 (the retro-axillary and axillary trunks of Ewart). Clinically, the posterior segmental bronchus is the most important segment in the right upper lobe (Brock, Hodgkiss, and Jones, 1942). Because of its posteriorly placed orifice, it is the first to become abscessed from particulate infected material inhaled or aspirated from the upper respiratory tract. Brock and his associates have demonstrated, experimentally, how quickly iodized oil passes into the posterior ramus of B^3 or lateral rami of B^3 and B^2 , depending on whether the patient is lying on the back or right side.

Incidentally, one is tempted to question Brock's preference for Neil's term "subapical." If this name for the posterior segment is intended to indicate that the segment is inferior to the apical segment then it should be pointed out that it is no more subapical than the anterior (pectoral) segment. If it is intended to mean that it is beneath the apical segment when the patient is supine, then posterior or dorsal is much more accurate. In fact, the anterior and posterior position of the "pectoral" and "subapical" segments are the ideas which it is most desirable to retain.

Similar objections may be raised to the use of the term "axillary" for the lateral branches of B^2 and B^3 . They do, indeed, project into the axilla, so that one can understand the usefulness of this term to surgeons, but it is vitiated by the use of the same term to designate lateral branches of the inferior lobes which certainly do not project into the axilla. For these and other reasons

it would seem that Jackson and Huber chose most wisely in employing, first, only the terms apical, basal, and lingular, which describe universally recognized parts of the lung, and second, only the terms anterior and posterior (ventral and dorsal), superior and inferior (cranial and caudal), and medial and lateral, which indicate the position of segments within a lobe. In thus selecting the terminology of Jackson and Huber as the simplest and most logical yet proposed, I do not wish to detract from the work of Brock which, perhaps, constitutes the most comprehensive and clarifying study of the bronchial tree that has appeared since the time of Ewart.

Incidentally, in discussing the surgical approach to the posterior segment, Brock (1942) has done a great service in demonstrating that the upper posterior level of the interlobar fissure is most commonly the fifth rib or interspace, that is, one or two segments lower than is given in most anatomic texts. Finally, he has presented most significant diagrams of the surfaces of the upper lobe, showing the variations in the extent of the three segments, that is, how the apical, the anterior, or the posterior segments may encroach upon each other's territory.

Between the upper and middle lobe bronchial orifices there is a stretch of the right bronchus (Ewart's bronchus intermedius) which is grooved anteriorly and laterally by the superior interlobar portion of the right pulmonary artery (Plates 5 and 6). For reasons which will be stated later, this is the level at which resection of the right inferior lobe sometimes has to be made (Kent and Blades, 1942a).

The Bronchi of the Middle Lobe.—The middle lobar bronchus, *M*, Fig. 1 (the cardiac of Ewart), usually arises slightly above the orifice of the superior bronchus of the lower lobe, *B⁶*. While appearing anteriorly to originate at the level of *B⁶*, its higher origin, even in this view, is indicated by a crest which descends obliquely from the medial side of the right bronchus (Fig. 1).^{*} Even so, the position of its orifice greatly complicates amputation of the lower lobe (Churchill, 1940). Conversely, septic material may drain into the middle lobar bronchus from an abscessed superior bronchus, especially if the patient is treated in a prone position (Brock, 1943). Furthermore, it may be strangulated by enlargement of the lymph nodes which surround it (Brock, 1943).

Commonly it divides into lateral and medial segmental bronchi, *B⁴* and *B⁵*, Fig. 1. The lateral segmental bronchus, *B⁴*, Plates 5 and 6, divides into a lateral ramus, *a* (the outer mammary-cardiac of Ewart), which supplies the lateral angle and lateral fourth of the middle lobe and a posterior ramus, *b* (the descending mammary-cardiac of Ewart), which supplies the middle portion of the lateral half of the lobe. The medial segmental bronchus, *B⁵* (the inner cardiac of Ewart), supplies the medial half of this lobe and divides into an anterior ramus, *a*, Plate 5 (the sterno-cardiac of Ewart), and a posterior ramus, *b* (the inner posterior cardiac trunk of Ewart). From Ewart's descriptions it would seem that in his specimens ramus *B⁴b* had shifted medially to become a branch of *B⁵*. Credence is lent to this view by the fact that ramus *B⁴b* is accompanied by a branch of the medial segmental artery, *A⁵x*, Plate 6. Also, in Brock's Fig. 48b, the median bronchus carries most of the branches. In another specimen, however, rami corresponding in distribution to *B⁴a*, *B⁴b*, and *B⁵b* of Plate 6 are all branches of the lateral segmental bronchus and all are accompanied by rami of the lateral segmental artery. This tendency for ramus *B⁴b* to shift

^{*}This is formed by the pressure of the right pulmonary artery. In the specimen shown in Fig. 1, the crest is occupied by a ramus of the bronchial artery.

in either direction may explain why three arteries of the middle lobe are said to be as common as two.

Apparently, therefore, there is considerable variation in the branching of the middle lobar division so that final determination of the prevailing pattern must await further study. Such shifting of branches from one segment to another would seem to complicate any attempt to resect either the middle or lateral segment by itself. In a personal communication, Blades wrote from the Walter Reed Hospital in Washington that he has never tried this since "it has always seemed that this dissection would be very difficult and the amount of lung tissue saved when the middle lobe is involved would not justify the additional technical difficulties."

The Bronchi of the Right Lower Lobe.—The first branch in the lower lobe is the superior segmental bronchus, *B'* (the posterior-horizontal distribution of Ewart, first hyparterial dorsal bronchus of Leby, or apical bronchus of Kramer and Glass). This arises from the posterior or slightly posterolateral aspect of the right bronchus at the beginning of the lower lobe. As Ewart remarked, "This distribution presents well-marked individuality." Frequently it is separated from the lower lobe by an incisure. Dévé (1900) noted that such a fissure was more common on the right side and in children. In 11 out of 180 right lungs the separation was complete and continued the plane of the secondary (horizontal) fissure. In 29 more there was an incomplete separation of the segment making a total of 22 per cent in which there was some degree of separation on the right side. Surgically the segment "can practically always be identified and removed separately" (Blades, personal communication). Likewise, it is one of the three segments in which abscesses commonly occur (Kramer and Glass).

Its mode of branching is variable, but I agree with Brock (1943) that there are three principal branches. Following Jackson and Huber's method of naming segmental bronchi, I have named them as follows: a superior ramus, *a*, Plates 6 and 7 (the superior of Brock or vertical ascending mid-dorsal of Ewart), a lateral ramus, *b*, Plates 6 and 7 (the axillary of Brock or deep mid-axillary posterior horizontal of Ewart), and a posterior ramus, *c*, Plate 7 (the paravertebral of Brock or vertical descending mid-dorsal of Ewart). Ewart, with his abhorrence of trifurcations, described rami *a* and *c* as having a rudimentary common trunk which he called the short superficial posterior trunk, but in Plate 7, *b* and *c* are the ones that have a common trunk. In fact, any two may originate together, but Brock's convincing injections leave no doubt about this essentially tripartite arrangement. Of the three rami, the lateral and posterior are most favorably placed to receive inhaled material. Of special interest is ramus *c* which may extend downward as far as the tenth rib, posteriorly, instead of to the usual limits of the segment, the eighth intercostal space (Brock, 1943). He also pointed out that the trunk of the bronchus is in contact with lymph nodes and therefore subject to bronchostenosis. One such node is shown in Plate 6.

Before passing to consideration of the basal bronchi it is necessary to mention an inconstant but independent subsuperior segmental bronchus, so named by Jackson and Huber, which is given off posteriorly (or somewhat posterolaterally) from the bronchial stem of the lower lobe just before the final bifurcation into lateral and posterior basal segments, *B**, Fig. 1 and Plate 7 (this is the lesser posterior horizontal distribution of Ewart and the second dorsal hypar-

terial bronchus of Aeby). Neil and co-authors (1939), as well as Brock (1943), gave this "subapical" branch the status of a segmental bronchus, since it is an independent trunk occupying the same relative position on the descending stem as the superior bronchus, except that it is 2 to 3 cm. lower down. Brock was able to identify it in 88 of 170 satisfactory bronchograms. His injections indicate that this posterior segment is interpolated between superior and basal segments and may extend as far as the midaxillary line. In Plate 7, it divides into a lateral ramus, *a*, and a posterior ramus, *b*. Its importance is due to the fact that its position makes it vulnerable to postural inhalation of infected material and that an abscess in this segment may coexist with one in the superior segment. Such an abscess usually presents in the paravertebral groove.

Between the superior and the remaining segmental bronchi of the lower lobe there is an interval of $1\frac{1}{2}$ cm. on the right bronchus (Fig. 1), which is the common stem of the four segmental bronchi which reach to the base or diaphragmatic surface of the right lung. At this level Churchill and Belsey (1939) were able to remove all basal segments, leaving the superior bronchus attached to the remainder of the lung.

The first to branch off is the medial basal segmental bronchus, *B'*, Fig. 1 (the retro-cardiac distribution of Ewart or cardiac bronchus of Aeby and of Brock). This is the infracardiac bronchus of the embryo. In quadrupeds it forms an independent lobe; there it was noted by Galen and subsequently by the Talmudists who called it "the little rose lobule" (Levin and Boyden, 1940). It bifurcates into an anterior ramus, *a*, Plate 6, and a posterior ramus, *b*, Plate 7 (the anterior and the posterior retro-cardiac rami of Ewart). The former distributes to the anteromedial, the latter to the posteromedial surfaces of the inferior lobe and its base. Its main stem is said by Brock to form a characteristic anteromedial curve. This is suggested in Plate 6 but is best seen in a lateral bronchogram. Below the point where the medial basal is given off the lower bronchial stem continues for a short distance, then appears to divide, in an anterior-posterior order, into three additional basal bronchi.

The anterior basal segmental bronchus, *B^a* (the anterior-basic distribution of Ewart), divides into lateral and basal rami, *a* and *b*, Plate 6 (the lateral anterior-basic and cardio-basic trunks of Ewart). Ramus *b* is the longer and reaches the extreme anterior base. The shorter, *a*, does not reach the base and thus appears to be a true lateral ramus supplying the costal as well as the anterior surface above the base.

The lateral basal segmental bronchus, *B^b* (the axillary-basic of Ewart and middle basal of Brock), is a replica of the anterior basal, lying more posteriorly and medially (Plate 6). It is the only segmental bronchus which is so overlaid by others that it cannot be well shown in either anterior or posterior dissections of the inferior lobe without removing intervening branches. It is barely visible in Plate 6. Like the other basal bronchi it divides into lateral and basal rami, *a* and *b* (the axillo-retro-mammary and the continued axillary-basic divisions of Ewart).

The posterior basal segmental bronchus, *B^c* (the posterior-basic distribution of Ewart), forms the largest of the basal segments and is the apparent continuation of the stem bronchus. In Plate 7 it can be seen bifurcating into a lateral ramus, *a*, and posterior basal rami, *b* and *c* (the lateral dorsi-basic and dorsi-basic divisions of Ewart). From a practical standpoint the lateral ramus is the most important (Brock, 1943), because next to the superior (and sub-

superior) bronchus it is vulnerable to the development of an abscess. Apparently the lateral rami of the basal bronchi are inconstant. Occasionally a branch like B^{10a} may arise independently from the stem bronchus.

THE LEFT BRONCHIAL TREE

Huntington (1920) explained the bilateral asymmetry of the human lung by suggesting that in the human embryo rotation of the heart (and sixth aortic arches) swings the right pulmonary artery ventrally, while rotation of the stomach swings the vagus nerve dorsally, thus creating room for the development and expansion of an eparterial bronchus placed high up on the dorsolateral surface of the right lung bud. Conversely, the same rotations of organs have brought the left vagus and left pulmonary artery together, thus closing off the corresponding area for expansion of the left bronchus. Be that as it may, the left superior lobar bronchus forms much lower down on the left side and arises from the anterolateral instead of the posterolateral surface of the stem bronchus (Fig. 1). If, further, we accept Huntington's conclusion that the lingular division of the left lobe corresponds to the middle lobar bronchus, M , and that the anterior segmental bronchi, B^2 , are comparable on the two sides, then the single apically directed trunk, B^{1+3} , of the left superior lobar bronchus may be considered an abbreviated representative of the apical, B^1 , and posterior, B^3 , segmental bronchi. Certainly on the right side these two trunks may give rise to four tiers of rami, while on the left side there may be only two. Correspondingly, the volume of the right apex is greater than that of the left.

The second region in which there is lessened expansion of the lung is in the medial basal portion of the inferior lobe. This is presumably due to the encroachment of the heart (see Fig. 1, cardiac curve of Aeby). Accordingly, the medial basal segmental bronchus is represented by only a medial branch of the anterior basal. Jackson and Huber (1943) have named the common stem thus formed the anterior-medial basal segmental bronchus. As a consequence of this fusion and that of the apical and posterior rami in the upper lobe, only eight instead of ten segmental bronchi are recognized in the left lung (Jackson and Huber). Since, however, the corresponding arteries are not reduced, the bronchi have been numbered the same on the two sides.

The Bronchi of the Left Upper Lobe.—The superior lobar bronchus divides soon after it leaves the left bronchus into ascending and descending trunks which Adams and Davenport (1942) have designated "upper" and "lower divisions" of the left upper bronchus, U and L , Fig. 2. The latter is also called the lingular division. The specimen shown in Fig. 1 differs from the usual pattern in that the anterior segmental bronchus, B^2 , fails to arise with the apical-posterior segmental bronchus, B^{1+3} , and has been displaced downward. But this is a common variation. Furthermore, it frequently happens elsewhere in the lung that a more or less intermediately placed ramus may shift up or down the fork or remain in the middle to give the familiar tripod appearance, for example, the right posterior segmental bronchus, B^3 , the posterior branch of the right lateral segmental bronchus, B^{4b} , Plate 6, and now B^2 of the left side.

As pointed out by Ewart, the upper division bronchus does not normally continue the direction of the superior lobar bronchus outward, as on the right side, but rises abruptly upward, thereby diminishing the vertical distance which exists between their points of origin on the stem bronchi. This is especially true of the first branch, the apical-posterior segmental bronchus, B^{1+3} (the axillary-

apical trunk of Ewart). Soon after its origin it divides into apical, B^1 , and posterior, B^2 , limbs. Several authors give these the status of segmental bronchi. The bronchoscopist doubtless prefers to consider these as subsegmental rami because the endoscopic view of the orifice of the upper lobar bronchus usually shows only two subdivisions, each of which is again subdivided into two bronchi. Another reason is that sometimes, as in the specimen shown in Fig. 2, the apical-posterior bronchus divides into three instead of two branches, ramus a then representing the combined B^1a and B^2a of Fig. 1.

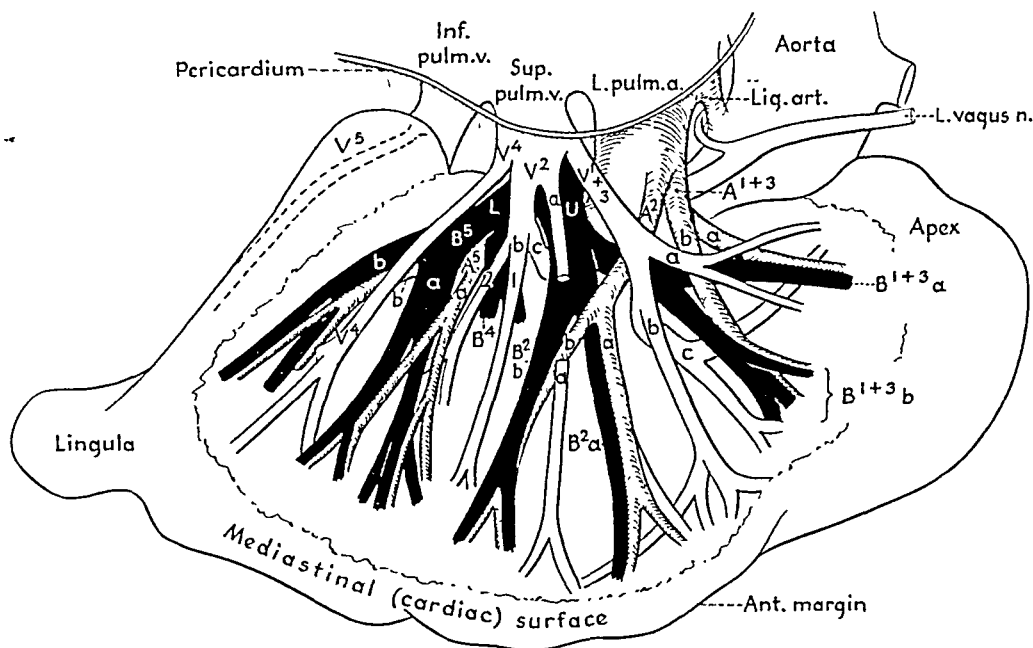


Fig. 2.—Dissection of anterior surface of left upper lobe from a second cadaver, a white man, aged 65 years ($\times 0.6$). This specimen differs from the one shown in the plates in five major respects: (1) The anterior segmental bronchus (B^2) arises with the apical-posterior (B^{1+2}) from the upper division (U) of the left superior lobar bronchus (this is the more usual origin) instead of from the lingular division (Li , Fig. 1). (2) There are two instead of three arteries supplying the upper division bronchi, due to the union of apical and posterior segmental vessels (A^{1+2}). (3) The anterior segmental artery (A^2) arises from a truncus anterior instead of with the lingular trunk (Plate 2). (4) The superior lingular bronchus (B^1) has no anterior ramus (see B^4b , Plate 1). (5) The inferior lingular vein (V^2) drains anomalously into the inferior pulmonary vein instead of into the superior pulmonary (see V^5 , Plate 1).

The apical limb, B^1 (the ascending apical distribution of Ewart), supplies the inner and anterior portion of the apex and subjacent area (Plate 1). It divides into an apical ramus, a , and an anterior ramus, b (the posterior ascending apical and continued anterior ascending apical of Ewart). Ewart's names would seem to imply that the two rami are comparable to the posterior and anterior parts of B^1 on the right side, but it seems more reasonable to consider the left B^1 as comparable only to the right B^1a . In any case, these bronchi are seldom the site of lung abscesses (Brock, 1943).

The posterior limb, B^2 (the axillary distribution of Ewart; or subapical bronchus of Neil and Brock), supplies the posterior apical and lateral apical regions (Plate 2). Brock stated that it extended to the apex in only one of fifteen specimens, but presumably he referred to the very summit of the apex for his figures show a distribution to the descending lateral and posterior slopes of the apex. This posterior limb divides into a posterior ramus, B^2a (the posterior axillary trunk of Ewart), and a lateral ramus, B^2b (the continued axillary trunk of Ewart). B^2b is smaller than on the right side and somewhat less vulnerable to abscess formation (Brock, 1943).

The anterior segmental bronchus, B^2 (the pectoral distribution of Ewart), should be a branch of the upper division of the superior lobar bronchus. The effect of its having drifted down onto the lower division in this specimen is to curtail the expansion of the lingular distribution, Li , Plate 1. As noted on the right side, the segments of the upper lobe may encroach upon each other, producing quite varying patterns. Usually, the anterior segment is the largest in the upper lobe. It divides into a lateral ramus, B^2a , Plate 2 (the outer pectoral trunk of Ewart or axillary pectoral of Brock), and an anterior ramus, B^2b (the sterno-pectoral trunk of Ewart). The lateral ramus, according to Brock (1943), is clinically the most important branch in the left upper lobe since it is as frequently abscessed as the posterior segment of the right upper lobe. When abscessed, it presents in the interlobar fissure (see Plate 2). Sometimes, in cases of bronchiectasis, the anterior segment is involved and is then removed with the lingular segments (Blades).

The *inferior or lingular division* of the superior lobar bronchus subtends an area in the left upper lobe which is considered the equivalent of the middle lobe. It is frequently separated from the rest of the lobe by an incisure. Its single trunk forks into superior and inferior segmental bronchi, the lower of which descends to the lingula, the "little tongue" or lobule at the anterior inferior angle of the upper lobe. Although Ewart applied the same terms to these bronchi as to those of the middle lobe, both Jackson and Huber (1943) and Brock (1943) have pointed out that the distribution is superior and inferior and not medial and lateral. I have ventured to add the adjective "lingular" in each case (namely, superior lingular, a contraction of "superior segment of lingular division") so that no two segments on the same side of the lung shall have the same name. Removal of this double segment (or just its inferior portion) has become an accepted procedure following the pioneer work of Churchill. The impelling reason for resecting it is the fact that in 80 per cent of cases with bronchiectasis of the left lower lobe the lingula is also involved (Churchill and Belsey, 1939).

The superior lingular segmental bronchus, B^4 (the anterior-cardiac trunk of Ewart), divides into a posterior ramus, a , Plate 2, and an anterior ramus, b , Plate 1 (the mammary-cardiac and sterno-cardiac divisions of Ewart). This is the third segmental trunk of the upper lobe to send rami to the lateral surface of the lung, the three being the posterior, anterior, and superior lingular bronchi. Sometimes, as in Fig. 2, only the posterior ramus is present.

The inferior lingular segmental bronchus, B^5 (the posterior-cardiac trunk of Ewart), bifurcates into two parallel rami, a and b (the posterior and anterior cardiac lobular branches of Ewart). Curiously enough, the angle which they subtend in Fig. 2 is much greater than that in Plate 1. To what extent this may be explained by the absence of ramus B^4b or the fact that the anterior segmental bronchus, B^2 , is a branch of the upper rather than the lower division necessarily awaits the study of more specimens.

The Bronchi of the Left Lower Lobe.—The superior segmental bronchus, B^6 (the posterior-horizontal distribution of Ewart) emerges from the posterior (or posterolateral) surface of the left bronchus just below the level of the left superior lobar bronchus (Fig. 1). As on the right side, there is barely room enough for amputation of the lower lobe. Anteriorly, the superior bronchus is in contact with the inferior trunk of the left pulmonary artery (Plate 2) and medially with the left vagus nerve and *aorta* (Plate 3). Like the corresponding

bronchus on the right, it subdivides into three trunks: a superior ramus, *a* (the ascending mid-dorsal oblique of Ewart or superior of Brock), a lateral ramus, *b* (the deep posterior-horizontal trunk of Ewart or axillary ramus of Brock), and a posterior ramus, *c* (the descending mid-dorsal oblique of Ewart or paravertebral ramus of Brock). Ewart correctly describes rami *a* and *c* as lying more posteriorly than *b*, but is not justified in considering them branches of a common trunk (the rudimentary superficial horizontal), since the mode of branching is not constant. (See discussion of right superior bronchus, *B^e*.)

The inconstant subsuperior segmental bronchus (*, Plate 3) will be considered with the posterior basal bronchus of which it is a branch.

The remaining bronchi of the left lower lobe belong to the basal segments. These differ from the corresponding bronchi of the right lung in two respects: first, in there being three instead of four segmental bronchi and second, in their mode of branching. Brock (1943) observed that in twenty-eight out of thirty specimens the branching on the left side was an apparent trifurcation, whereas on the right such an arrangement occurred in only five cases.

The first basal branch is the anterior-medial basal segmental bronchus, *B⁷⁺⁸* (the anterior-basic distribution of Ewart). It supplies the district which corresponds to the combined medial and anterior segments of the right side. It divides into two principal branches, a medial basal ramus, 7, and an anterior basal ramus, 8 (the cardio-basic and mammary trunks of Ewart). In Fig. 1 the former has been somewhat shortened in order to show underlying branches. Its proper length is indicated in Plate 2, but while it has been numbered 7, for practical purposes (chiefly for the numbering of arteries) it is not given the name "medial basal segmental bronchus"; for *B⁷* of the left side is not to be considered the equivalent of *B⁷* of the right side. The latter is an independent bronchus which arises early from the stem bronchus of the embryo and acquires in most mammals the status of a lobar bronchus. The corresponding region in the left lung is relatively undeveloped and has been taken over by a branch of the anterior basal. Ewart specified a particular branch (see *B^{7b}*, Plate 2), calling it the left retro-cardiac distribution. The anterior basal ramus, 8, gives off a true lateral branch, *B^{8a}*, Plates 2 and 3, which distributes to the costal surface above the base of the lung.

The lateral basal segmental bronchus, *B⁹* (the axillary-basic distribution of Ewart) is larger and more posterior than on the right side and may be seen in a dissection of the posterior surface (Plate 3), whereas on the right side it could be glimpsed only from the anterior dissection (Plate 6). It divides into a smaller lateral ramus, *a* (the retro-mammary axillary trunk of Ewart), and a larger basal ramus *b*, which continues the direction of the common trunk (the continued axillary-basic of Ewart).

The last segmental bronchus on the left side is the posterior basal, *B¹⁰* (the posterior-basic distribution of Ewart). The first branch to emerge from this trunk is the subsuperior (*, Fig. 1 and Plate 3), so named because it descends under cover of *B^{9c}*. In this specimen it arises unusually low down and so has lost the status of a segmental bronchus. Apparently its distribution is more lateral than posterior. On the right side the corresponding branch, *B^{*}*, arises from the common stem of *B⁹* and *B¹⁰*. Two centimeters below the origin of the subsuperior, the posterior basal bronchus gives off a ramus, *b*, to the vertebral border of the lung (the inferior descending aortic of Ewart). The main stem, *a*, then continues to the base of the lung. There seems to be no lateral branch to

the costal region above the base, but as Brock has pointed out such "axillary" branches are inconstant.

In concluding this brief description of the segmental bronchi and their first subdivisions, it is only fair to point out that while there have appeared numerous variations which either were not encountered by Ewart or were deliberately omitted (perhaps in the belief that it were better to concentrate on the detailed description of a given specimen) nevertheless, his account was so precise that it is possible to recognize from his description the pattern which various specimens have in common.

THE ARTERIES OF THE RIGHT UPPER LOBE

As Herrnheiser has pointed out (1942), the form of the normal hilar shadow is determined chiefly by the vascular system, hence its importance to roentgenologists. But the arteries are even more important to the surgeon who must ligate them individually. For this reason it is perhaps necessary to disagree with Herrnheiser's statement that "the development of the vessels in the lungs, as elsewhere in the body, shows constancy in the essential points," and that the extensive parallelism between right and left lungs makes it sufficient to "discuss only one lung, the right one." In fact, the arteries are more variable than the bronchi and the veins than the arteries.

The problem of inconstancy is encountered at once. The right upper lobe has three segmental arteries. The first branch of the right pulmonary artery is usually the common stem which supplies apical and anterior segments, A^1 and A^2 , Plate 4. The third artery lies deep to these and usually is visible only in the interlobar portion of the hilum (A^3 , Plate 5). On the left side, A^1 and A^2 less frequently arise from a common stem (Fig. 2) and A^2 may even originate in the interlobar fissure as a branch of the stem which supplies the segments of the lingular division (Plate 2). Therefore, it seems inadvisable to accept the definition that the "superior trunk constitutes the main artery of the upper lobe" (Herrnheiser, 1942, p. 597) but to restrict the use of this term to the occasions when all three arteries have a common trunk. The term "truncus anterior" is suggested for the common arrangement shown in Plate 4, in which A^1 and A^2 emerge as a common stem on the anterior aspect of the hilum.*

The apical segmental artery, A^1 , Plate 4 (the apical of Herrnheiser and Kubat and ascending axillary-apical of Ewart), arises, usually, with A^2 from the truncus anterior which lies between the corresponding vein and bronchus. In this specimen it distributes to the branches of the apical bronchus only, that is, to the first two tiers of bronchi, $B^1a1 + B^1a2$, and B^1b ; but if the posterior segmental artery, A^3 , is poorly developed then a third ramus (either not present in this specimen or representing an extension of one of these) may plunge deeply into the apical and subapical region and supply several subdivisions of the posterior bronchus, particularly B^2a (Ewart). Herrnheiser and Kubat named the three stems in their specimens the mediastinal, costovertebral, and costal rami, yet their distribution corresponds neither to the rami described by Ewart nor to the three which have been lettered a , b , and c in Plate 4.† This is due to two

*Herrnheiser's division of the right pulmonary artery into three trunks has not been followed for several reasons. The "truncus superior" is not uniformly the common stem for the three primary arteries of the upper lobe. The "truncus intermedius" and the "truncus inferior" are not trunks but successive parts of a continuous vessel. Furthermore, the line drawn between intermediate and lower trunks is so oblique that the two parts overlap. A much more natural division is into a *pars* (or truncus) *anterior* and a *pars interlobaris*, that segment of the artery which is exposed at the two interlobar fissures (Figs. 3 and 4).

†These authors seem not to have understood Ewart's description since they gave as synonyms for the three different arteries Ewart's name for a common trunk and its two divisions. Furthermore, they gave the same names and distributions for the three arteries of the left apicoposterior segment, B^{1+2} , as they gave for the right apical segment, B^1 . Obviously these are not comparable.

factors: (1) the tendency for a ramus to extend beyond its corresponding bronchus (for example, A^1c supplies not only B^1a2 but B^1a1b); and (2) the variation in the number of bronchial rami, as when the tiers of bronchi in the apical-posterior region vary from two to four. (See, also, discussion of posterior segmental artery.) In view of these extensive variations it seems futile, at present, to attempt to name the rami of the right apical artery. These facts also destroy the illusion that the apical and posterior segments can be considered to be bronchovascular units. They are bronchial distributions, only.

The anterior segmental artery, A^2 , Plate 4 (the pectoral of Ewart and of Herrnheiser and Kubat), is described as having a variable origin, although the arrangement in Plate 4 is a common one. Frequently it arises separately from the right pulmonary artery, in the hilar portion of the secondary fissure. Appleton (1944) stated that as a rule a smaller part of the segment is supplied by another artery in the fissure. In Plate 4 it divides into two major branches—a lateral ramus, a (the mid-pectoral of Ewart or costo-pectoral of Herrnheiser and Kubat), and an anterior ramus, b (the sterno-pectoral of Ewart and of Herrnheiser and Kubat). The latter branch extends to the inferior angle of the upper lobe.

The posterior segmental artery, A^3 , Plate 5 (the inferior axillary of Ewart or axillary of Herrnheiser and Kubat), is variable not only in size and distribution but in its origin. It may arise as a deep portion of the truncus anterior or from the interlobar portion of the right pulmonary artery (Plate 5). Kent and Blades (1942b), referring to this as an "accessory upper lobe artery," stated that it is the commonest anomaly on the right side, that it sometimes occurs below the origin of the artery to the superior segment of the lower lobe, and that ligation of it, when the lower lobe is being removed, is of no consequence. However, if it were an artery the size of A^3 (Plate 5) ligation of it would eliminate at least two-fifths of the arterial distribution to the upper lobe, for here it accompanies the third and fourth tiers of bronchi in this part of the lung, namely, all the branches of B^2 . Appleton stated that "as a rule" about one-half of the posterior segment is supplied by this "posterior ascending artery" and that sometimes it may form a common stem with the superior segmental artery, A^6 . In the specimen figured here it divides into a posterior ramus (a) and a lateral ramus (b , Plate 5).

THE ARTERIES OF THE MIDDLE LOBE

Since lateral and medial segments are recognized in the middle lobe, corresponding segmental arteries should be expected. These arise from the interlobar portion of the right pulmonary artery, either from a common trunk, the artery of the middle lobe (the cardiac of Ewart), or separately, A^4 and A^5 , Plate 5. Appleton wrote that the latter is "generally" the arrangement, but according to Kent and Blades the latter type of origin occurs in only 25 per cent of cases.* Herrnheiser and Kubat said that the artery of the middle lobe divides as frequently into three as into two major rami. This is probably due to the tendency of ramus B^4b (Plate 6) to occupy an intermediate position between medial and lateral sides of the lobe.

The medial segmental artery, A^5 (the para-mediastinal ramus of Herrnheiser and Kubat), supplies the cardiac surface of the middle lobe, its medial angle (Plates 5 and 6), and the medial interlobar surfaces. It divides into anterior

*These authors (1942b) referred to the lower artery, A^4 , as an "accessory" middle lobe artery, but it should not be considered an "extra" one.

(a) and posterior rami (b, Plate 6). It also sends off a ramus π (the descending costal of Herrnheiser and Kubat) which accompanies ramus B^2b . The lateral segmental artery, A^4 (the costal ramus of Herrnheiser and Kubat), is therefore defective in this specimen, its branch A^4b being replaced by A^5x . Its ramus π (the axillary costal of Herrnheiser and Kubat) supplies the lateral angle and one-third of the middle lobe.

THE VEINS OF THE UPPER AND MIDDLE LOBES

The veins of the upper and middle lobes are the tributaries of the right superior pulmonary vein. In reading the accounts of various authors it is apparent that there is as much variation in their arrangement as in the names that have been applied to them. In order to keep the terminology consistent and simple it has been necessary to coin new terms.

The first and most superficial tributary is named the apical-anterior vein of the upper lobe, V^1 , Plate 4; (this is the subpleuro-mediastinal vein of Herrnheiser and Kubat). As the name suggests, it receives two main tributaries, one apical, a , and one anterior, b , which drain the corresponding segments; (these are the apico-mediastinal and sterno-mediastinal rami of Herrnheiser and Kubat). With the exception of one lateral branch, V^1b1 , which runs between apical and anterior segments, the course of the vein is largely subpleural.

The next to be encountered in an anterior approach is the inferior vein of the upper lobe, V^2 , Plates 4 and 5 (the pectoral of Herrnheiser and Kubat). It courses along the inferior margin of the upper lobe, the margin bordering the secondary or horizontal fissure. It may run along either the anterior or interlobar surface (Plate 5). It drains the inferior portion of the anterior segment.

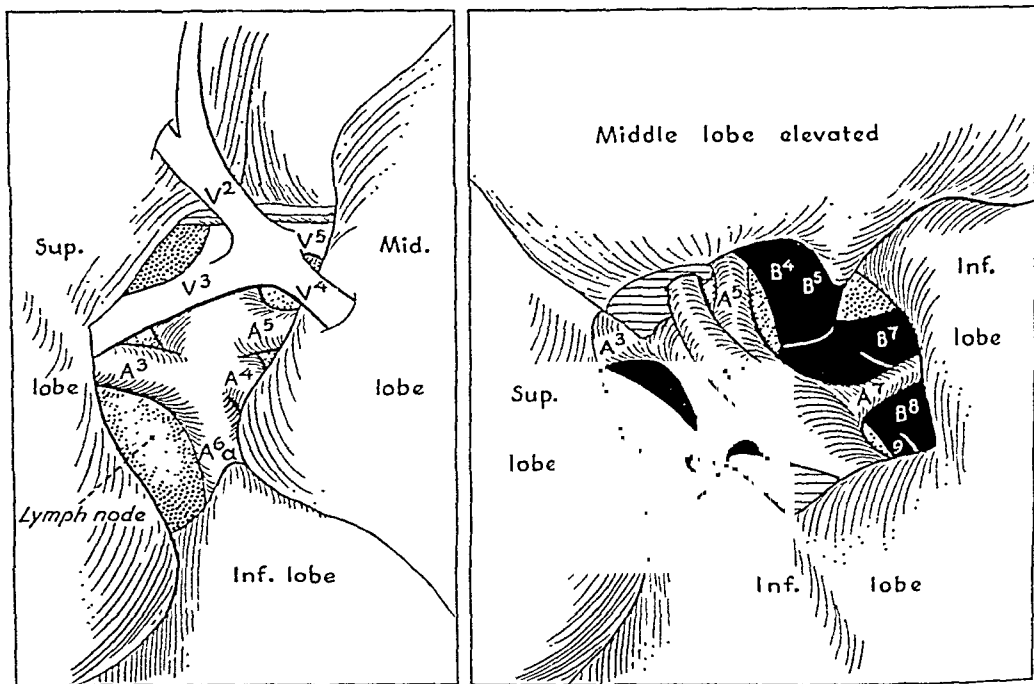
The third, the largest and most deeply placed branch of the upper lobe is the posterior vein of the upper lobe V^3 , Plates 4 and 5 (the combined apical and axillary veins of Herrnheiser and Kubat). According to Ewart, Herrnheiser and Kubat, Melnikoff, and in one of our specimens, this vein emerges from the upper lobe between B^2 and B^3 , but in the specimen shown in Plate 5 the main vein lies posterior to all arteries and bronchi. It receives three principal tributaries. Ramus a drains the posterior region of the apex and the territory of the third and fourth tiers of bronchi (that is, the branches of B^3). Ramus b (the apico-central vein of Herrnheiser and Kubat) is centrally placed in the lobe between the apical and posterior bronchial distributions. Ramus c (the axillary vein of Herrnheiser and Kubat) emerges from between the posterior and anterior bronchial distributions, B^3 and B^2 , Plate 5).

The two veins of the middle lobe empty into the superior pulmonary vein either as one trunk or more commonly as two trunks (Plate 5). They emerge usually from between the anteriorly placed arteries and the posteriorly placed bronchi. However, in the specimen shown in Plate 5, the lateral vein of the middle lobe, V^4 (the costal vein of Herrnheiser and Kubat), crosses the medial artery, A^5 , anteriorly. In this position it lies deep to the inferior vein of the upper lobe, V^2 , Plate 4, a position which might cause it to be accidentally ligated on removal of the upper lobe.

The medial vein of the middle lobe, V^5 , Plate 5 (the para-mediastinal of Herrnheiser and Kubat, is normal in position. Both veins lie medial to the corresponding arteries and branch in such a way as to drain not only the territory of the corresponding bronchi but also contiguous areas of adjacent bronchi (V^4a , Plate 5 and V^5a , Plate 6). A special interest is the small anomalous,

ginal vein indicated by an asterisk in Plate 5. This is the interlobar (accessory) ramus of Herrnheiser. It empties into the posterior vein of the upper lobe (see orifice on V^3) and its occurrence is rendered possible by the incomplete separation of the upper and middle lobes.* Kent and Blades also mentioned rare instances in which a vein of the middle lobe drains directly into the left atrium to form a third pulmonary vein.

On the interlobar surface no venous connections were found between middle and lower lobes, although Kent and Blades (1942a) found the fissure incomplete in 12.5 per cent of their specimen.



Figs. 3 and 4.—Sketches of the hilar portions of the secondary (horizontal) and interlobar (oblique) fissures before dissection (see Plates 5 and 6). In the secondary fissure (Fig. 3) all the branches of the right superior pulmonary vein are shown but V^1 (the apical-anterior vein); V^2 and V^3 are inferior and posterior veins of the upper lobe, V^4 and V^5 , lateral and medial veins of the middle lobe. Four segmental arteries are visible, the posterior (A^3) of the upper lobe, the lateral (A^4) and medial (A^5) of the middle lobe, and the first ramus of the superior artery (A^{6a}) of the lower lobe. In the interlobar fissure (Fig. 4) elevation of the middle lobe has exposed the middle lobar bronchus and its two segments (B^4 and B^5), and two of the basal segmental bronchi (the medial basal, B^7 , and anterior basal, B^8) together with the artery to the first (A^4). The other bronchi of the lower lobe (B^6 , B^9 , and B^{10}) arise within the substance of the lung, although B^9 is just visible in the hilum.

THE ARTERIES OF THE RIGHT LOWER LOBE

The first of the arteries of the right lower lobe are the superior segmental arteries, A^{6a} and A^{6b} , Plates 6 and 7. Ordinarily they arise as a single trunk (the apico-horizontal artery of Herrnheiser and Kubat) from the postero-lateral aspect of the interlobar portion of the right pulmonary artery (Figs. 3 and 4), at or slightly below the origin of the arteries to the middle lobe. This would be about the position of A^{6a} in Plate 6. (Incidentally, A^6 may arise with A^5 from a common trunk.) In this specimen, however, A^6 is represented by two widely separated branches, a superior ramus, A^{6a} , arising in the inter-

*Kent and Blades (1942a), in dissecting 227 lungs immediately post mortem, observed that the secondary or transverse fissure of the lung was absent in 21 per cent (20 per cent, Hovelacque, and associates 1937; 10 per cent of 100 specimens, Brock, 1943) and incomplete in another 67 per cent of specimens (51 per cent, Hovelacque and associates; 53 per cent, Brock). Accordingly, in three- to four-fifths of the lungs there is opportunity for interlobar veins to develop.

lobar fissure and the combined lateral and posterior rami, A^6b and c , arising from the pulmonary artery in the substance of the lung, well below the interlobar fissure (Plate 6). Herrnheiser and Kubat showed a similar subdivision on the left side (their Fig. 33). It is obvious that such a wide separation of the arteries would somewhat hinder removal of the segment. Both the upper and lower arteries, A^6a and A^6b (the apical and horizontal rami of Herrnheiser and Kubat, are faithful replicas of the corresponding rami of the single superior segmental bronchus, B^6 . Of special importance is ramus A^6c , Plate 7 (the vertical descending mid-dorsal artery of Ewart or the superior retro-bronchial artery of Herrnheiser and Kubat). This sometimes extends downward in a paravertebral direction as far as the lower third of the lower lobe and so would have to be ligated in removing the basal segments.

The only other artery of the lower lobe which takes origin in the interlobar fissure (Fig. 4) is A^7 , the medial basal segmental artery (the anterior basal of Herrnheiser and Kubat).^{*} It divides into anterior and posterior rami, A^7a and b , which follow the corresponding bronchial distributions (Plates 6 and 7). Sometimes it arises with A^8 , from a common trunk (Ewart).

The remaining basal arteries arise from the inferior portion of the pulmonary artery, deep within the substance of the lung. The anterior basal segmental artery, A^8 (the anterior axillary basal of Herrnheiser and Kubat), is well displayed in Plate 6. Its tripod appearance is due to the early subdivision of its lateral branch, a . The lateral basal segmental artery, A^9 (the posterior axillary basal of Herrnheiser and Kubat), is shown dividing into its lateral ramus, a , and basal ramus, b , in Plate 6. It is too deeply situated to be visible in Plate 7. The beginning of the posterior basal segmental artery A^{10} is barely visible in Plate 6. Frequently it has a common origin with A^9 . Before it divides into its principal lateral, a , and basal rami, b and c , Plate 7, it gives off a forked subsuperior stem, A^{10} , with lateral and posterior branches which have the same relative position as the higher A^6b . The lateral branch, $A^{10}a$ represents the posterior axillo-horizontal of Herrnheiser and Kubat (the lesser posterior-horizontal of Ewart). The posterior branch, $A^{10}b$, represents the inferior retro-bronchial artery of Herrnheiser and Kubat. Both of these branches are as variable in presence and origin as the subsuperior bronchus.

In summarizing the arteries of the inferior lobe it may be stated that they seem to follow the corresponding bronchi much more closely than those of the upper and middle lobe, as if the pattern in the lower lobe had become relatively fixed.

THE VEINS OF THE RIGHT LOWER LOBE

The veins of the right lower lobe are all tributaries of the right inferior pulmonary vein. The latter enters the right atrium not only inferior but posterior to the superior pulmonary vein (Plate 4). It is somewhat hidden by the inferior lobe and by the upward extension of the anterior layer of the pulmonary ligament. While usually operated upon from above, this vein and its branches are best displayed from the posterior surface. In the specimen shown in Plate 7, it has a somewhat atypical appearance, as of a bent tree, with most of the branches reaching outward from its convex side. In the majority of specimens, however, it resembles a low shrub with branches radiating from the ground. It is also variable in its distribution.

^{*}Apparently Herrnheiser and Kubat have erred in considering this the anterior basal artery of Ewart. It would also seem that these authors have misinterpreted Ewart's description of other basal arteries, for nearly all their synonyms are incorrect. Perhaps this is due to the fact that the bronchi were omitted from their studies.

The first branch, the superior vein of the lower lobe, V^6 (the apico-horizontal of Herrnheiser and Kubat), consists of two rami, V^6a and V^6b , which in the specimen shown in Plate 7 enter the main stem separately. Usually they unite before crossing the stem bronchus posteriorly. The branches of V^6a occupy the zone superior to and between the two rami of the superior segmental bronchus (Plates 6 and 7); those of V^6b occupy the zone inferior to B^6 , between it and B^* (Plate 7) and between B^6 and B^8 and 9 (Plate 6). Its position illustrates well the intersegmental nature of the venous drainage. Doubtless if the superior segment were separated surgically, ramus V^6b could be removed with the superior segment or be left attached to the basal segments.

The medial basal vein, V^7 (the retro-cardiac of Ewart or anterior basal of Herrnheiser and Kubat), arises anteriorly from the inferior margin of the inferior pulmonary vein (Plates 6 and 7). In general it courses medial to the bronchus of the same name and drains the region anterior to and between the rami of B^7 (Plate 6).

The anterior basal vein, V^8 (the anterior-basis of Ewart or anterior axillo-basal of Herrnheiser and Kubat), is a centrally placed vein the main trunk of which courses deep and inferior to B^8 (Plate 6) and anterior to $B^9 + ^{10}$ (Plate 7). Its three principal tributaries occupy the zones between B^8 and B^9 (V^8a and b , Plate 6), the zone between the branches of B^8 (V^8b) and the zone between B^7 and B^8 (V^8c).

The lateral basal vein, V^9 (the posterior axillo-basal of Herrnheiser and Kubat), is to be seen only in Plate 7. Its peripheral rami occupy the zone between the branches of B^* and B^{10} and between these bronchi and the lateral segmental bronchus, B^9 , which lies hidden beneath the structures shown in Plate 7. In some specimens it passes anterior instead of posterior to the basal division of the right bronchus, as it enters the inferior pulmonary vein.

The posterior basal vein, V^{10} (the posterior-basis of Ewart, or posterior basal of Herrnheiser and Kubat), is the terminal branch. It begins (rami a and b) between the lateral basal and posterior basal bronchi, then swings inferior and posterior to B^{10} to enter the inferior pulmonary vein. It collects tributaries from the zone between B^7 and B^{10} (ramus $V^{10}c$) and from the medial posterior basal region, $V^{10}d$.

THE ARTERIES OF THE LEFT UPPER LOBE

In contrast to the right side (where the order of structures in both antero-posterior and inferosuperior directions is vein, artery, and bronchus) the order on the left side is vein, bronchus, and artery. As a consequence the five segmental arteries to the upper lobe are scattered along the arched superior and posterior (interlobar) surface of the pulmonary artery. Therefore, as Kent and Blades (1942a) have pointed out, the arrangement does not lend itself to mass ligation of the root of the upper lobe, since such a technique may jeopardize the blood supply of the lower lobe. Blades succeeded in doing it, however, by cleaning the upper lobe bronchus (after ligating the arteries) and then dividing it at about the point where the lingular division begins (personal communication).

The arteries to the upper lobe were said by Melnikoff to vary from three to six (oftener from three to four). Kent and Blades said from four to seven. Ewart and Felix each mentioned four. In the specimen which is shown in Plates 1 and 2 there are only three trunks (if the arteries of the anterior

segment and lingular division be counted as one); also in the specimen shown in Fig. 2, there are only three (the lingular trunk being counted as one). A partial explanation for the larger numbers quoted is that the segmental trunks are so short that frequently their rami arise separately from the pulmonary artery.

The first branch of the left pulmonary artery is an apicoposterior trunk (the apical of Herrnheiser and Kubat, or ascendens of Melnikoff). It arises on the convex superior surface of the pulmonary artery and, according to Melnikoff, is most commonly a sessile trunk which divides immediately into apical, A^1 , and posterior, A^2 , segmental arteries (the mediastinal and costovertebral arteries of Melnikoff). Such is approximately the pattern shown in Plate 1. Herrnheiser and Kubat gave a very different description. They described this sessile trunk as breaking up into three rami (costovertebral, mediastinal, and costal) and such is the condition shown in Fig. 2, namely, rami $A^{1+2}a$, $A^{1+2}b$, and ramus $A^{1+2}c$. (Ramus c is visible only from the interlobar side.) The two types can be reconciled when it is understood that artery $A^{1+2}a$ (Fig. 2) has an anterior and posterior ramus. Should the former unite with A^1 and the latter with A^2 instead of with each other, the pattern would resemble that of the specimen shown in Plates 1 and 2.

The apical segmental artery, A^1 , Plate 1 (the anterior ascending apical to Ewart), arises on the anterosuperior surface of the pulmonary artery. It divides into an apical ramus, a , and an anterior ramus, b . These branches seem to correspond to the mediastinal and superior oblique rami of Melnikoff. The latter is considered by Herrnheiser and Kubat to be a misplaced branch of A^2 (which they named the ascending costo-pectoral), but this seems improbable since the artery has the same position in Fig. 2 ($A^{1+2}b$), even although A^2 has a different origin than in Plate 1.

The anterior segmental artery, A^2 , Plate 1 (the pectoral of Ewart), arises in this specimen in the interlobar fissure as a branch of the lingular trunk (Plate 2). Appleton said that an interlobar origin is common and pointed out that this artery then begins below the first artery of the inferior lobe, A^6a , Plate 2. It divides into an anterior ramus, b , Plate 1 (the sterno-pectoral of Herrnheiser and Kubat, the transverse mediastinal of Melnikoff), and a lateral ramus, a , Plate 2 (the axillary of Herrnheiser and Kubat, the transverse interlobar of Melnikoff). In Fig. 2, a very different origin of A^2 may be noted. Here it is a branch of the truncus anterior of the left pulmonary artery, and it consists only of ramus b ; that is, ramus a and the corresponding bronchus, B^2a are absent.

The posterior segmental artery, A^3 , Plate 2 (the posterior ascending apical of Ewart or costovertebral of Melnikoff), accompanies the branches of the posterior segmental bronchus which are outlined in Fig. 1. As seen in Plate 2, it originates in the interlobar fissure from the superior-posterior surface of the left pulmonary artery. It divides into a posterior ramus, a , and a lateral ramus b .

Somewhat less variable than the arteries which have been described are the vessels which accompany the lingular division of the upper lobe bronchus. Usually the two segmental arteries arise from a common trunk (Plate 3), the truncus lingulae (of Backman or the cardiac of Ewart), but occasionally (as in Fig. 10 of Kent and Blades, 1942a) they arise separately from the pulmonary artery. Again they may originate with the anterior segmental artery, A^2 ,

a truncus communis (Plate 2). Such an arrangement would complicate removal of the lingula. Also, Kent and Blades have pointed out that the lingular trunk may arise below the level of the first artery to the lower lobe, A^6 .

The superior lingular segmental artery (of Felix; the costal ramus of Herrnheiser and Kubat) usually divides into anterior, A^4b , and posterior, A^4a rami. It is thus truly superior, but in Fig. 2 only the posterior ramus and bronchus are present, hence the name "dorsolateral" sometimes applied to this segment by recent authors.

The inferior lingular segmental artery, A^5 , Plates 1 and 2 (the paramediastinal ramus of Herrnheiser and Kubat), is of special interest since the segment it supplies is frequently removed separately (Churchill, 1940). In Fig. 2, it is better developed than in Plate 1. It divides into two major branches.

THE VEINS OF THE LEFT UPPER LOBE

As on the right side, the veins of the upper lobe are all branches of the superior pulmonary vein except for an occasional anomalous vessel (Fig. 2). They differ from the veins of the right lobe in that all of them empty into the superior pulmonary vein superficially. Therefore, the central and posterior portions of the lobe are not drained by a posterior vein but by deep branches of three anterior trunks. Ewart explained this on the ground that there is no intervening pulmonary artery between veins and bronchi, hence the veins can pass directly to their distribution. The three trunks are named after the corresponding bronchi, namely, the apical-posterior, anterior, and lingular. Corresponding numbers have been assigned to them, also, to avoid confusion. Ewart described two modes of branching, a less common type (Fig. 2) in which the last two trunks unite before entering the pulmonary vein, and the more common type (Plate 1) in which the first two are confluent. Herrnheiser and Kubat were of the opinion that the latter is the less common type.

The highest branch is the apical-posterior, $V^1 + ^2$, Plate 1 (the apical of Ewart and Herrnheiser and Kubat). As the name signifies, it divides into anterior rami, V^1a and b and posterior rami, V^2a and b . The former (the mediastinal branches of Melnikoff) drain the anterior subpleural surface, the region between the branches of B^1 and the region between B^1 and B^2 (Plate 1); the latter branches (the costovertebrals of Melnikoff) drain the interlobar surface and the regions between the branches of the posterior bronchus (Plate 2), then course between the apical and posterior bronchi, next between the apical-posterior and anterior bronchi (Plates 1 and 2) to reach the anteriorly placed main trunk.

The middle trunk is the anterior vein, V^3 , Plate 1, (the pectoral of Ewart). Like the apical-posterior, it divides into anterior and posterior branches. The latter, V^3c , may be seen in Plate 2, occupying the zone between the anterior and the superior lingular segments.

The lowest of the three venous trunks is the lingular, $V^4 + ^5$, Plate 1. It divides into superior lingular, V^4 , and inferior lingular, V^5 , veins (the superior and inferior cardiac veins of Ewart). The former carries a posterior branch, V^4a , Plates 1 and 2 (the costal of Herrnheiser and Kubat), which occupies the zone between superior and inferior lingular bronchi. In Fig. 2, V^5 is a branch of the inferior pulmonary vein.

In contrast to the right side, therefore, the left upper lobe presents three trunks instead of the five (or four) to be found in the right upper and middle

lobes. This may be explained by the confluence of anterior and posterior rami, which is possible in a thinner lobe, and to the lesser development of the segments of the lingular division as compared to those of the middle lobe.

THE ARTERIES OF THE LEFT INFERIOR LOBE

The highest artery of the lower lobe is to be found in the interlobar or oblique fissure (Plate 2), an incisure which is incomplete in approximately 70 per cent of specimens (Kent and Blades, 1942a). This is the left superior segmental artery, A^6 , Plate 2. In this specimen it is anomalously double. Its rami, a and b , leave the pulmonary artery at some distance from each other. The origin of the upper ramus is higher than the origin of the lingular arteries, a circumstance which would complicate resection of the lower lobe. Also, in this specimen, the anterior segmental artery, A^5 , arises anomalously with the lingular artery from a truncus communis. The branches of A^6 follow faithfully the corresponding bronchi. Branches a and b (the superior and lateral rami) are best displayed in Plate 2. Ramus c (drawn a little small) may be seen in Plate 3. As pointed out in the discussion of the bronchi, the posterior ramus, c (the superior retro-bronchial of Melnikoff), may overlap the basal segments in supplying the middle third of the vertebral portion of the lower lobe.

The basal segmental arteries follow their respective bronchi. The medial basal, A^7 (the anterior basal of Herrnheiser and Kubat),^{*} crosses beneath B^8 , in the specimen shown in Plate 2, to reach the posterolateral side of B^7 . Usually it passes superficial to B^8 to reach the anterolateral side of its companion bronchus.

The anterior basal segmental artery, A^8 (the anterior axillo-basal of Herrnheiser and Kubat), pursues the usual course to reach the anterolateral side of B^8 .

The remaining basal arteries are best seen in Plate 3. These are the lateral basal segmental artery, A^9 (the posterior axillo-basal of Herrnheiser and Kubat) and the posterior basal, A^{10} (the posterior-basic of Ewart and Herrnheiser and Kubat). The latter is anomalous in origin and position. Instead of branching lower down with A^9 , it is the first of the basal branches coming off from the left pulmonary just inferior to the superior bronchus, a circumstance which might complicate resection of the superior segment. Furthermore, it runs on the posteromedial instead of the posterolateral side of its bronchus.

THE VEINS OF THE LEFT INFERIOR LOBE

The five principal veins of the inferior lobe are all branches of the inferior pulmonary vein. The mode of branching can be seen in Plate 2.

The superior vein, V^6 (the apico-horizontalis of Herrnheiser and Kubat), descends almost vertically to empty into the superior border of the inferior pulmonary vein. Its two tributaries, a and b , Plate 3, are retrobronchial. The superior ramus, a (the apical of Herrnheiser and Kubat), drains the upper two-thirds of the superior segment; the lateral ramus, b (the horizontal of Herrnheiser and Kubat), the lower third. In another specimen a descending branch of V^6b drains the zone between the posterior basal bronchus and the pleura, perhaps taking over the territory drained by V^9a (Plate 3).

^{*}Herrnheiser and Kubat gave as a synonym the *axillary* basic artery of Ewart, but this is unquestionably the *anterior* basic artery of Ewart. Similar confusion attends the naming of synonyms for most of the other basic arteries.

In accordance with the union of medial basal and anterior basal segments on the left side, the corresponding veins arise close together (Plate 2), instead of being widely separated (Plate 6). The medial-basal vein, V^7 (the anterior basal of Herrnheiser and Kubat), traverses the plane between the medial and lateral basal segments (Plates 2 and 3). The anterior basal, V^8 (the anterior axillo-basal of Herrnheiser and Kubat) traverses the plane between the anterior basal, B^8 , and lateral basal, B^9 , bronchi. In Plate 2, there is a medial marginal vein which has been interpreted as a branch of V^7 and labeled as ramus c .

The remaining two veins, V^9 and V^{10} , have a common stem (Plate 2). These are the lateral basal, V^9 (the posterior axillo-basal of Herrnheiser and Kubat), and the posterior basal, V^{10} . The former traverses the plane between lateral and posterior basal segments (Plate 3), the latter the plane between medial and posterior basal zones.

TOPOGRAPHICAL RELATIONS AT THE HILUM

Anterior Surfaces.—On both roots of the lung the phrenic nerve (and associated pericardiophrenic arteries) must be avoided in ligating the superior pulmonary veins (Plates 1 and 4). This nerve lies just anterior to the root of the lung and deep to the mediastinal pleura between that layer and the pericardium. Churchill and Belsey (1939) especially cautioned avoidance of it in adhesions to the pericardium. (In Plates 1 and 4 no attempt has been made to show the mediastinal pleura. The phrenic nerves mark the position where it is reflected, from the pulmonary ligament and root of the lung, onto the mediastinum.)

Inferiorly, in following the pulmonary ligament up to the inferior pulmonary vein, and ligating the latter, the esophagus and its adnexa should be avoided. It will be recalled that the pulmonary ligament is reflected onto the mediastinum at the level of the esophagus and that it is usually attached to the esophageal fascia. In this tissue (Plate 3) may be found esophageal arteries (branches of the aorta or of the bronchial arteries) and the vagus nerves. In one case an anomalous bundle of longitudinal muscle was found running upward from the outer coat of the esophagus to the left stem bronchus (dagger, Plate 3). In Plate 7, a large right bronchial artery may be seen passing along the upper surface of the esophagus, just above the right inferior pulmonary vein. Its origin and proximal relations may be followed in Fig. 1. (In this specimen the entire system of bronchial arteries for both sides of the lung originated from a single vessel coming from the inferior surface of the aortic arch.) Kent and Blades (1942a) spoke of the bronchial arteries as being variable, too small to ligate, and of no surgical importance. However, their relations to the esophagus and its blood supply might warrant further investigation.

Superiorly, on the left side (Plate 1), the upper lobe is in contact with the left superior intercostal vein, the one which sometimes participates in the formation of a left superior vena cava (left common cardinal vein). There is also a relation to the left recurrent laryngeal nerve (Plate 3). Amputation of the left bronchus, with consequent traction on the pulmonary nerve plexus or ligation of the left pulmonary artery (Plate 1), might traumatize the recurrent nerves.

On the right side, the superior vena cava and azygos vein, the right vagus and phrenic nerves are to be avoided (Plates 4 and 7). According to Brock (1940), the right pulmonary artery is covered by a peculiar triangular fascia the apex of which connects it with the superior vena cava (see Plate 4). In

order to expose the artery and to separate it from the vena cava this lumen must be cut.

Finally, attention is called to the pulmonary lymph nodes which fill the crevices between the vascular and tracheobronchial tubes. In lymphadenitis these can strangulate the large bronchial divisions, particularly the middle lobe bronchus as mentioned earlier in the text. Nelson (1932) related these nodes to the four large bronchial divisions on each side which he called secondary bronchi, namely, two upper divisions (upper lobar bronchi), two ventral divisions (middle lobar and lingular), two dorsal divisions (superior segments of the lower lobe), and two lower divisions (lower lobe bronchi). While his classification of some twenty nodes was doubtless a simplification of patterns (see account of pulmonary nodes in Rouvière he performed a service in emphasizing these topographical relations.

DISCUSSION

Nelson's conception of the lung as consisting of four major bronchial divisions on each side which may or may not be separated by fissures (to wit, the upper, middle [seu lingular], posterior, and basie—the terminology is ours) is an arresting conception and has much to recommend it. Churchill and Belsey's contention that these are bronchovascular segments is doubtless true, although such "lobes" are frequently supplied not by one but by several vascular trunks. However, in any formal classification of orders of magnitude, I agree with Huber that it is more logical to consider the customarily accepted lobes of the right and left lung as the largest segments, Adams and Davenport's upper and lower divisions of the left upper lobe as the next largest, the bronchopulmonary segments ("distributions" of Ewart) next, and so on down to the smallest units, which would be Miller's lung lobule.

Of these categories, the bronchopulmonary segment has claimed most attention in recent years, originally because it was recognized to be the seat of lung abscess (Ewart, Kramer and Glass) and more recently because of the success in resecting segments in bronchiectasis. Because in a practical way some segments have proved to be "surgical units," a tendency has arisen to conceive of them morphologically as bronchovascular units. Thus, they have been defined as subdivisions that are "surrounded by planes of avascular tissue, uncrossed by bronchi or blood vessels beyond the hilus" (Adams and Davenport, 1942). In the light of the present anatomic study this seems questionable. Certainly in many specimens the arteries of the right apical bronchus cross the plane separating the apical from the posterior segments, and in the middle lobe the medial segmental artery may cross the plane separating medial from lateral segments. Furthermore, throughout the lung the peripheral veins lie in the intersegmental planes and drain the blood from adjacent segments. Consequently, as Appleton has pointed out, "if an intersegmental plane is opened with a view to partial lobectomy, the tributaries of a collecting vein must of necessity be divided on one side or another." It is suggested, therefore, that the bronchopulmonary segment be defined as the zone of distribution of a major bronchus which may or may not be entered by arteries from adjacent segments and which is drained peripherally by veins occupying intersegmental planes.

CONCLUSIONS

Seven plates and supplementary figures are presented showing the origin and distribution of the segmental bronchi and associated blood vessels, and their relation to each other and to adjacent structures in the vicinity of the hilum.

These dissections have confirmed the conclusions of Jackson and Huber (1943) that there are ten principal bronchopulmonary segments in the right lung. These are the nine "distributions" described by Ewart in 1889, with an additional one obtained by counting the two rami of the middle lobe bronchus as one. On the left side eight are recognized.

Jackson and Huber's nomenclature has been retained since these terms are believed to be the simplest and most consistent. They are as follows: superior lobe (apical, anterior, and posterior segments), middle lobe (lateral and medial segments), inferior lobe (superior, medial basal, anterior basal, lateral basal, and posterior basal segments).

The left lung is considered to be made up of eight segments: segments of the upper division of the upper lobe (apical-posterior and anterior), segments of the lower or lingular division (superior and inferior), segments of the inferior lobe (superior, anteromedial basal, lateral basal, and posterior basal).

Ten principal arteries have been identified on each side. They have been given the names of the bronchial segments of the right side.

Ten principal veins have also been identified in each lung. These have been given the names of the bronchi which lie superior and adjacent to their proximal stems, except the first two veins of the right superior lobe. These have been named apical-anterior and inferior.

In general, the arteries follow the peripheral distribution of the bronchi while the veins, after leaving the root of the lung, assume an intersegmental position.

The veins are more variable than the arteries and the arteries more variable than the bronchi. The more common variations have been listed.

From the standpoint of the relation of segmental arteries to bronchi, the least stable segments of the lung seem to be the apical and posterior of the right upper lobe and those of the middle lobe. In the former the extent of the bronchial ramifications is variable and there is a strong tendency for the right apical artery to accompany portions of the posterior bronchus. Similarly, in the middle lobe, there is a tendency for the medial artery to supply the lateral bronchus.

Finally, notwithstanding the ease with which some segments can be resected surgically, the bronchopulmonary segment should not be considered to be a morphologic bronchovascular unit. It is merely a bronchial distribution with intersegmental planes that may be crossed by arteries from adjacent segments and that contain veins which drain all contiguous segments.

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ADDENDUM

After this article had gone to press the July issue of the *English Journal of Anatomy*, containing A. B. Appleton's comparative study of the arteries and veins of the right upper lobe in fifty specimens reached the University Library. Since it is the most detailed statistical account yet to appear, certain observations especially pertinent to this article have been recorded here.

Perhaps the most outstanding contribution is the author's analysis of the extent to which segments of the right upper lobe are supplied by arteries from adjacent segments. Thus, in 22 per cent of specimens the posterior segment was supplied exclusively by "recurrent" branches of the apical segmental artery; in another 8 per cent it was supplied wholly or in part by branches of the anterior ("pectoral") segmental artery; and in another 2 per cent by branches of the middle lobe artery. Similarly, the apical segment was partly supplied by rami of the anterior segmental artery (14 per cent) and the anterior ("pectoral") segment by branches of either the apical or middle lobe artery (8 per cent).

A second point to which attention should be called is the extent to which the anterior segment and the posterior segment are supplied by arteries arising from the interlobar portion of the right pulmonary artery (Appleton's "ascending" branches of the "lower division" of the artery). Thus, in 42 per cent of specimens the anterior segment was partly supplied (and in 6 per cent, wholly supplied) from this source. Less surprising was the fact that in 32 per cent of specimens the posterior segment was wholly supplied (and in 44 per cent, partly supplied) by arteries arising from the interlobar part of the artery.

With respect to the veins, Appleton's plan of naming deep peripheral rami by the intersegmental planes which they occupy is excellent. Less felicitous are his terms for the large proximal trunks: for example, designating the posterior vein (*V*₃, Plate 5) as "great upper lobe vein," affords no clue to its position. Of special interest to surgeons is his discussion of the approaches to the bronchovascular pedicle of the right upper lobe, and the different vascular patterns encountered in the interlobar approach.

A NEW DESIGN FOR RAISING A TUBED PEDICLED FLAP

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THE CLASSIC METHOD OF RAISING A PEDICLE

THE usual way of preparing a tubed pedicled flap according to Gillies,¹ Barsky,² or Fomon³ is shown by Fig. 1.

Gillies described accurately how to close the corners at the union of the tube with the edges of the donor site, which are commonly called "triangular corners." Following this technique the closure of the corners is complete. To facilitate the closure it has been advised that the incisions should be staggered.

With this technique the tubed pedicled flap lies exactly over the donor area, with the result that the suture line of the pedicle is on its undersurface and lies directly over the suture of the donor area, or over the dressing of the graft if the defect has been covered by a skin graft. It is not unusual to find that in suturing the corners, a certain degree of tension exists. In fact, Barsky remarked that, "short tubes are difficult to suture and rotate."

When for any reason (hematoma, infection, failure of the graft, sloughing of any edge, etc.) there is some complication in the pedicle or the donor area, or—as is more common—in the corners between them, it becomes difficult to do the proper dressing between the pedicle and the donor area. The healing of the triangular corners may be slow. Should edema from infection or any other cause supervene, the difficulty in dressing may be greater and the facility for spreading infection may increase.

I have encountered these complications several times in the work of very experienced plastic surgeons and, of course, in my cases too. Is it possible to avoid many of these difficulties?

THE FUNDAMENTALS OF THE NEW TECHNIQUE

Four Essential Points to Consider.—To lessen these difficulties a method should be found which would: (1) allow the flap and the donor area to be treated separately, (2) render both lines easily accessible, (3) facilitate the closure of the ends, and (4) place the suture of the triangular corners of the pedicle outside the main suture line of the donor area.

The Basic Consideration.—To attain these objects the tubed pedicled flap should be longer than the straight distance between the ends of the donor area. By the classical method these lengths are exactly the same.

The solution from the geometrical point of view is quite simple if we consider that in a semicircle or any arch the diameter, or the straight line between the ends of the arch, is always shorter than the arch itself. Thus, if we design the pedicle in a curved line, the tube will be longer than the straight distance between its ends and therefore loose over the donor site. The shorter the radius of the curve of the flap, the looser will be the pedicle over the donor area (Fig. 2).

This point has limitations in practice, above all the ones coming from the blood supply, with which we shall deal later.

By examining the drawings it can be seen that the excess length of the pedicle in relation to the straight line allows us to bring the tubed pedicled

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flap away from the donor area, making all the suturing and any necessary maneuver easier.

Since the first pericle was raised, Nov. 17, 1942, the technique has been slightly altered and improved by experience.

THE TECHNIQUE

The planning of the pedicle is an important step. Very seldom is the same type of flap useful in two different patients. Before raising the pedicle it is necessary to decide such points as (a) the area from where the flap is to be

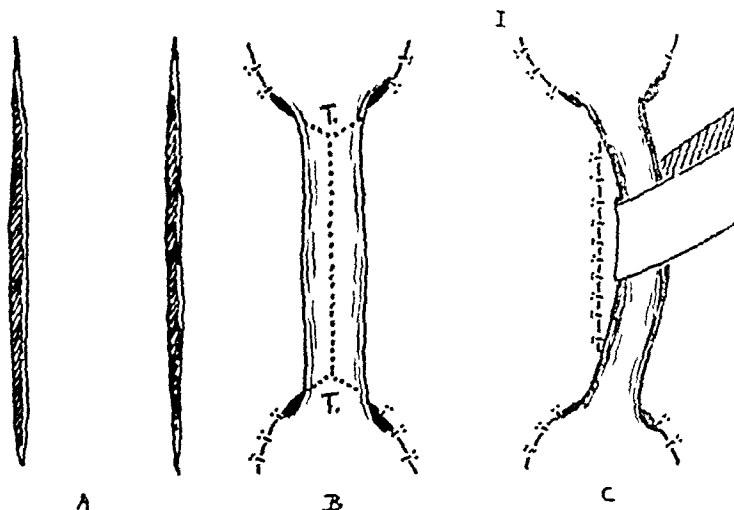


FIG. 1.—The classic method of raising a tubed pedicled flap. A, Two parallel incisions of the skin designing a rectangle; all the skin is undermined and rolled in. The donor site, after undermining, may be closed or skin grafted. B, The stitches of the pedicle are exactly superimposed to the stitches of the donor area. T, The so-called triangular corners, one on each side. C, The suture of the donor area is covered by the pedicle. The sutures of the pedicle are completely under it. To reach the suture of the donor area it is necessary to pull the pedicle aside.

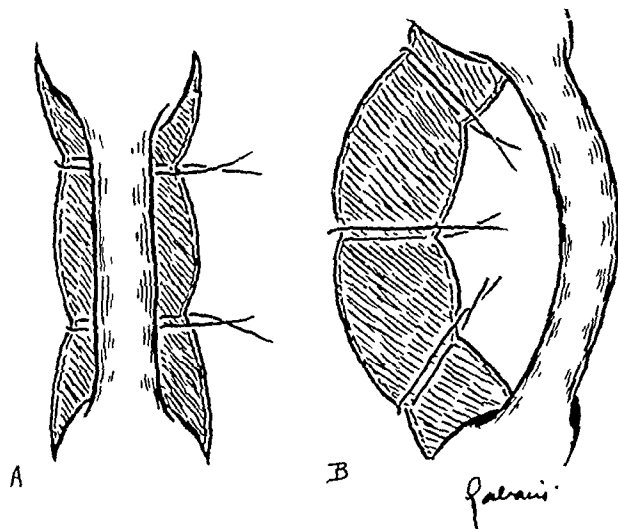


FIG. 2.—The main difference between the classic and the new method of raising a tubed pedicled flap is shown. A, The pedicle is kept over the donor area with the tension of the normal skin. To bring the pedicle to one side, it is necessary to force it. The suture of the donor site should be done from symmetrical points from the edges. B, The pedicle remains easily outside the donor area and it is quite loose. No effort is necessary to bring it to one side. The pedicle is displaced with the same arch as it was cut from the donor site.

raised, (b) the size and curvature of the flap, (c) the number of stages, (d) the necessity of any delay operation, (e) the way to transfer the pedicle to its final position. All these conditions are interdependent and should be decided before the first operation.

The Curvature.—The curvature should be adapted to the size of the flap and to the local condition of the blood supply.

In small pedicles the curve should be pronounced, with a short radius. A radius of 5 or 6 cm. for the inner curve may be adequate. In these small flaps the blood supply is not likely to suffer and the design may be practically any, from a very curved line to an almost angular flap, although acute angles should be avoided.

In large pedicles the curvature should be less and, therefore, of longer radius. A radius of 10 cm. or more in length is most suitable for the inside curvature. It may be dangerous to cut large pedicles following very pronounced curves because of some interference with the blood supply. However, if an unusual curvature were necessary in many cases it might be obtained by delaying the flap before the main operation, or by building up the flap in stages.

The Size.—I have been able, with this technique, to raise tubed pedicled flaps of very different sizes. The smallest flap has been 11.5 by 4.5 cm.; the standard has been about 18 by 7.5 cm. These two sizes can be considered orthodox and be raised at the first operation without undue danger.

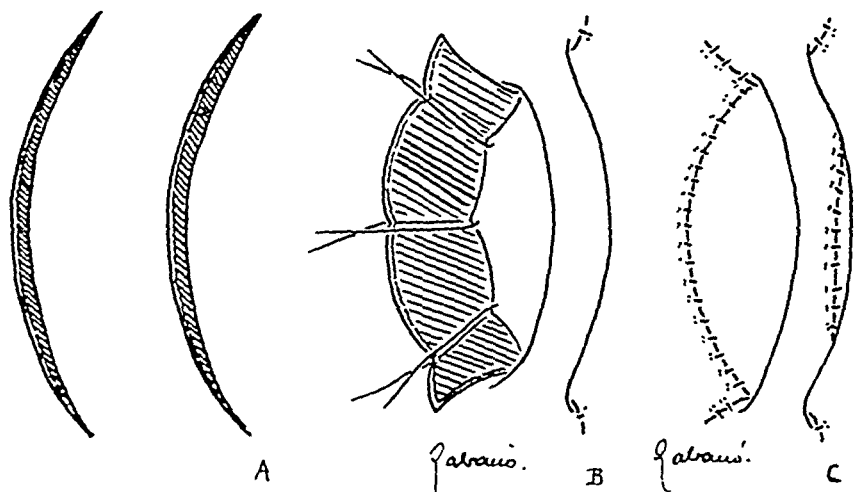


Fig. 3.—The method devised by the author of this article. *A*, Two parallel curves starting and finishing at the same level mark the edges of the pedicle. The skin is raised and rolled in. Radius of the inside curve is 5.5 cm. *B*, The stitches of the donor area are not inserted in the symmetrical points but radially, with the object of bringing the flap more to the side of the center of the curvature. *C*, All the sutures are in place. The central sutures of the flap are at the edge or over the flap. The sutures of the corners and of the tubed pedicled flap are described in the text and additional illustrations.

One of my large flaps was 23 by 8 cm., raised from the side of the abdomen. It was made in two stages: at first the edges of the pedicle were cut completely and sutured back immediately as a "delay"; in the second stage the flap was raised completely.

My longest flap, of a completely unorthodox size, was 33 cm. long by 7.5 cm. wide. It was raised from under the axilla and on to the back of the chest. The design was forced by the position of the areas which were available. It was raised in two stages. The first stage was to raise a pedicle 19 by 7.5 cm. and the second stage consisted of prolonging this pedicle by 14 cm. more, with the same width. The angle between both pedicles was about 90 degrees. The result was quite satisfactory.

The Raising of the Pedicle.—Once the size and the curvature are decided, two curved parallel lines are painted in ink on the skin. It is not necessary to use a divider, in fact, I always do it by hand, taking careful measurements. This allows me to make any slight modification which may be necessary to adapt

the design to the selected area. Sometimes the ends of the curve do not follow exactly the curvature of the central part; they may be straighter.

The skin to be tubed is now completely raised. All the edges of the donor area are undermined for at least 2 or 3 cm. all around, but sometimes much more. This is the time to decide if the donor area can be closed by direct suture or if a skin graft will be necessary to cover it. On the abdomen it is very often possible to close completely the donor site by direct suture, even in the case of large flaps. Sometimes the removal of some subcutaneous tissue may help to make the closure easier.

In any case there is no difference in the technique of this closure of the donor area following this new technique or the classical one, except at the corners, as will be explained later.

Now the flap should be tubed. Holding the edges with hooks or carefully with the fingers, the sutures will be placed, keeping the skin as it lies, without tension. I place a central stitch first, which, it can be seen, is not underneath the pedicle, but at one side or slightly on the upper side. Holding this stitch up, a few interrupted sutures will bring all the edges of the flap together. The central part of the flap is now completely sutured. The ends are still open.

The donor area should now be sutured. To begin, a few stitches, three or five, will bring the edges as close as they can be without undue tension. These stitches *should not* be inserted at the same level at both edges. They should follow a radial direction (see Fig. 3B). It will be seen that this facilitates the approximation of the ends of the pedicle, which is a very important part of this technique. If it has been decided that the donor area should be covered by a skin graft, the same type of stitches should be placed approximating the edges and they should be kept until the graft has been inserted and then removed.

The suture of the ends of the pedicle is not difficult but it is slightly "tricky." Because the flap is fairly loose the corners are easily accessible. The suture should be done as is shown in Fig. 4. The flap is kept as much as possible to one side and *this side of the end of the flap should be completely sutured to the edge of the donor site.* The other side should have very few sutures from the end of the pedicle to the edges of the donor area, sometimes none. *Part of this end of the pedicle should be sutured by at least two or three stitches to the other side,* the side toward which the pedicle is displaced. By this very essential maneuver the suture of the tubed pedicle is made entirely independent of the suture of the donor area. There should be two triangular corners at each end of the flap and all the sutures should be placed without tension. If tension is necessary, it is because the flap has not been brought enough to one side or the curvature of the design was too shallow.

Once finished, the tubed pedicle stands quite easily away from the donor area, sometimes 3 or 4 cm. at its center. If the donor area has been closed by direct suture the result is even better. If a graft has been put over the donor area, the dressing covering it remains almost completely at one side of the pedicle, but not beneath it.

I do not employ drainage anywhere at the end of the operation. If in some exceptional cases I am not quite certain that the area will remain dry, I may leave two stitches undone at one end, to facilitate the drainage of any possible collection. The dressing, always a very important part of the operation, is done with gauze, sometimes slightly wet; fair pressure is always applied over the donor area and at the ends of the flap, but only very light pressure is left

the central part of the flap. The central part is left always visible or just covered by a simple superficial bandage, to permit examination at any time.

DISCUSSION

Have the four essential points been obtained?

1. Is it possible to treat separately the flap and the donor area? The examination of Fig. 5A makes this evident.

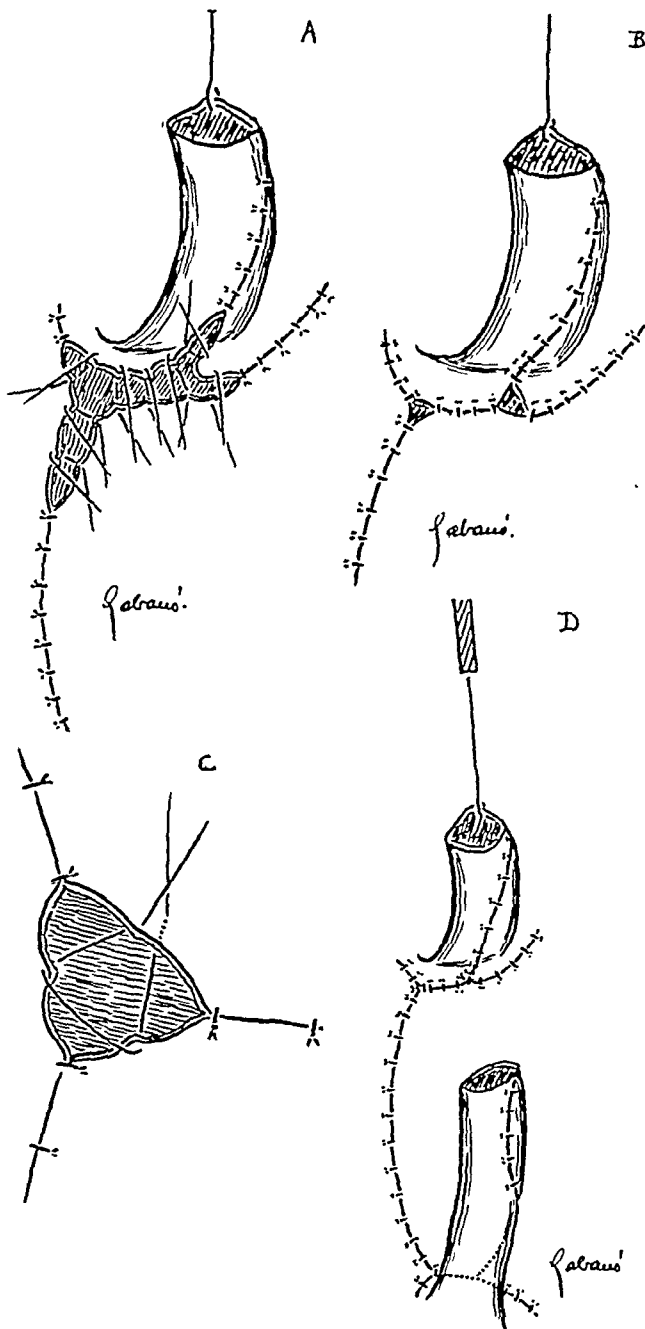


Fig. 4.—How to suture the triangular corners. (The flap has been cut and raised to show the suture of the corners.) A, The flap is kept to the side of the center of the curvature. The end of the flap of this side should be completely sutured to the edge of the donor site. The other side of the end of the flap should be sutured by only two or three stitches to the same side of the donor area and by, at least, two or three stitches to the side of the center of the curvature. B, The main sutures are in place. It remains to close the triangular corners. With this technique there are four triangular corners, two at each end. C, One of the sutures which can be used to close the central part of the triangular corners. The accurate closure of these triangles is very important. D, All the sutures are in place. Notice the independence of the suture of the pedicle and of the donor site.



A.

B.

Fig. 5.—A, The tubed pedicle flap can be easily lifted and all the suture lines are easily exposed. Flap and donor site can be treated separately. This pedicle was raised on July 17, 1943. B, The tubed flap at rest remains at one side of the donor area. This flap was used successfully to rebuild the pharynx.

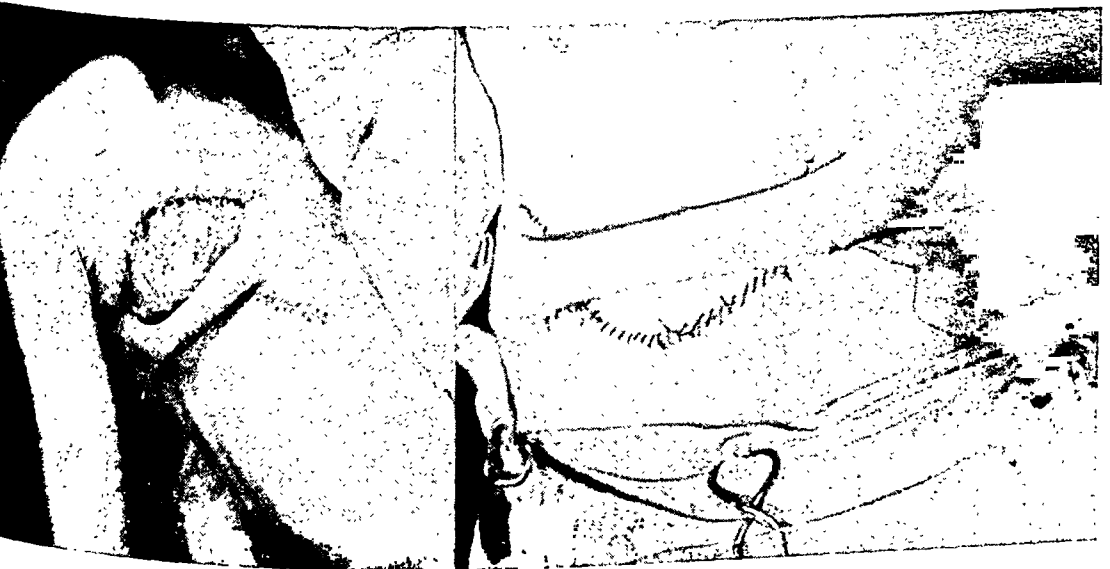


Fig. 6.—Note that the stitches of the tubed pedicle flap are lateral and the central one is slightly over the flap. This flap is 19 cm. long by 7.5 cm. wide and it was later prolonged in angular line with another pedicle in verticle direction 14 cm. long and with the same width. The whole is to be transferred to the left axilla and to the entire anterior part of the neck, deeply burned. No incidents have occurred and the flap is already inserted by the two ends on the sides of the neck.

Fig. 7.—Tubed pedicle flap 15 by 7 cm. The donor area was closed by direct suture. The pedicle stands apart from that suture. Because the flap is loose it is easy to push it up or to examine the corners. Note that three stitches can be seen at the center of the flap. There is no strain anywhere. The pedicle was raised on June 28, 1944.

2. Are both lines of suture easily accessible? From the donor area point of view this is obviously so. The suture of the pedicle becomes almost completely lateral and, if the curve is very pronounced, some of the stitches may be on the external surface of the flap. This is shown clearly in Fig. 6.

3. Is the closure of the ends facilitated? Yes, inasmuch as the pedicle is longer it is much more loose and there is much more room for maneuvering.



Fig. 8.—Flap 20 cm. long by 7.5 cm. wide raised from the abdomen without delay and following the technique described in this article. It is on the way to the neck, via chest, which had been burned deeply by x-ray therapy. The transfer has already been done quite successfully.

4. Is the suture of the triangular corners of the pedicle outside the main suture of the donor area? If the pedicle has enough curvature and during all the suturing it has been kept apart from the donor area, it will be seen that the suture of the flap and the suture of the donor area remain easily separated although there is a line of suture between them. If this is not easy it is because the flap has not been brought enough to one side. This lateralization should come easily; if not, it means that there has been some defect in following the technique explained.

In no case should the tubed pedicled flap be sutured forcing its position. The stitches should unite edges which lie easily together.

If the donor area instead of being sutured is grafted, the main sutures remain much the same, perhaps easier to place, because there is less tension at the edges of the donor area. In this case I would advise the suturing of the ends of the pedicle only at one side of the donor area and covering the other side with

the graft, as can be seen in Fig. 5B. The position of the triangular corners should be exactly the same as in the case of complete suture of the donor area.

Perhaps at first sight it may appear that the technique is complicated, but if the method described is followed from the beginning it will be found that the details become obvious when the pedicle is in the hand.

RESULTS

Following this technique I have raised twenty tubed pedicled flaps of very different sizes, from 11.5 by 4.5 cm. to 33 by 7.5 cm. (the latter in two stages).

In sixteen cases the result was quite satisfactory from the beginning. In three cases there was a small blue spot at the center of the flap, followed by a very superficial loss of skin which recovered completely in less than ten days.



Fig. 9.—The relationship of the main artery and the blood supply of a long flap. A central forehead flap of the up-and-down type to be used for a rhinoplasty. There is no main artery described in any anatomy textbook which goes up from the left eyebrow, across the midline, and down to the right side of the forehead. The blood supply is provided by the net of small vessels of the scalp and forehead. The result was quite uneventful.

In only one case was there a very small loss. It was in a flap 20 by 8 cm. raised in one operation, without any previous delay, on the upper part of the left thigh (to be brought down to the heel of the right foot). In the center of the flap there was a loss of skin 1.5 cm. long by 0.6 cm. wide. The whole pedicle is at this time in quite good condition to follow the plan devised.

This was the only case with any loss, which probably could have been avoided by a simple "delay."

Blood Vessels and the New Technique.—Is this technique made difficult because the direction of the vessels does not allow enough freedom to select the necessary curve? The answer is, "No, not if done properly," for the following reasons.

1. Although in practically all books on plastic surgery the main vessels are mentioned as the most important consideration in the design of a pedicle, this is not always quite so. It is too long a matter to be explained completely in this article but I shall mention three facts. I have raised, after careful consideration, long flaps of completely unorthodox design, from the point of view of the blood vessels, and successfully. Blair⁴ shows some flaps raised without any relationship to the main vessels. The typical up-and-down central forehead flap, a quite sound flap, is, too, unorthodox from this point of view.

2. In a small and wide flap, say 12 by 7 cm., the large vessels are not of much importance and frequently the flap can be raised with safety in any direction. It should be mentioned in particular that these short flaps are the ones which need a marked curvature to obtain the necessary extra length.

3. With long and narrow flaps, in which the big vessels must be considered, the curvature necessary to obtain the extra length is very small and often is just the degree of curvature which the vessels normally possess. But it is always possible by careful "delays" to raise successfully flaps which do not follow the line of the vessels.

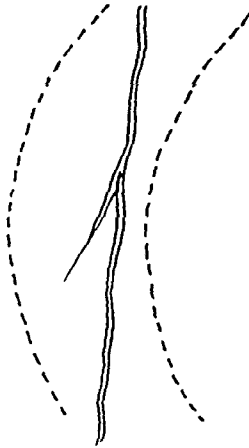


Fig. 10.—Straight vessel. If desired it is still possible to keep the main vessel within a pedicle cut on the curve.

Let me remark, also, that if a straight vessel is wanted it is often possible to enclose it inside the curved pedicle (Fig. 10).

Thus far I have not encountered a case in which it was impossible to cut the flap as described here and I have found the technique very helpful.

SUMMARY

A new technique is described for raising a tubed pedicled flap. This is largely based on a design whereby the tubed pedicle is cut on the curve, thus making the pedicle lie lateral to the donor area, simplifying all suturing, and making the pedicle much more free. The so-called triangular corners of the end of the tube are sutured apart from the main suture of the donor area, thus simplifying the nursing care.

The technique is fully described with illustrations.

The tubed pedicled flap and its donor area become independent from the first operation.

The results of twenty cases are discussed.

The photographs were taken by Miss H. Marsden and by Miss E. Gibbons.

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RESUSCITATION OF SEVERELY WOUNDED CASUALTIES

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SINCE the American forces landed in North Africa in November, 1942, many changes have occurred in the concepts and management of peripheral circulatory collapse. Our present views on resuscitating and treating severely wounded battle casualties are based on two years' experience in caring for such cases. This experience was gained from rendering resuscitation therapy and surgery to the most seriously wounded which were selected in division clearing stations and sent to adjacent field hospital platoons. These platoons were staffed by shock and surgical teams of an auxiliary surgical group, one of the shock teams being headed by one of us (J. J. L.), and one of the surgical teams by the other (J. M. M.). Prior to working in field hospital platoons, the former, during the North African and Tunisian Campaigns, served as shock officer in an evacuation hospital. Since the beginning of the Anzio-Nettuno Beachhead operation in Italy, he has supervised the resuscitation of over 1,500 battle casualties. It was early recognized that whole blood was the most essential agent to be used in combating wound "shock." The collecting and transporting of fresh whole blood in adequate quantities were the biggest problems which confronted the medical officers in forward hospitals. Up until the Anzio-Nettuno Beachhead landings it was necessary to draw blood from available military personnel at the time that the blood was to be used. A British Field Transfusion unit landed on D-Day of that invasion and furnished blood to the American forces. Soon after the beachhead was established, low titer group O blood was sent to forward hospitals by an American General Medical Laboratory. The blood transfusion program has been one of the most important, elaborate, and satisfactorily worked-out projects of World War II. Now one has available all the blood needed as far forward as the field hospital platoon.

THE "NONTRANSPORTABLE" CASUALTY

It was expedient that some method of classifying the wounded be adopted so that the seriously injured could be treated early and would not be exposed to unduly long ambulance rides. Therefore, individuals requiring immediate care were listed as "nontransportable," which implied that they were not to be

evacuated beyond the platoons of field hospitals without surgery. The patients in the nontransportable group need not necessarily have peripheral circulatory failure. The nontransportable casualties included principally: penetrating and perforating wounds of the peritoneal and pleural cavities, and of the spine; traumatic amputations; compound fractures of the femur; and vascular injuries necessitating the application of a tourniquet. Multiple combinations of these injuries were commonly seen in the group.

The patients were young, vigorous, healthy men, seldom over 25 years of age, who had been exposed to extremes of weather, had existed on irregular or inadequate diets, and who had experienced the stress of battle. Practically all had had morphine, often $\frac{1}{2}$ gr. subcutaneously, before arriving at the field hospital. Water had been denied to practically all of those with abdominal wounds, while others received none or minimal amounts before admission. All were subjected to evacuation over rough roads. Fractured extremities were supported with Thomas or wire ladder splints. Plasma, from one to six units, had been given to about one-third of the wounded in battalion aid, collecting, or clearing stations. Approximately one in fifteen of the extremity cases had a tourniquet in place on admission. Evacuation time to the field hospital was commonly six to twelve hours under usual circumstances, but was as long as eighteen to twenty-four hours in mountainous terrain.

GROUPING OF CASUALTIES BASED ON TRAUMA AND CIRCULATORY STATUS

A further classification of these patients based on trauma and circulatory status was helpful. The latter was adopted because it guided the priority and speed with which resuscitation was carried out and served as an index of the degree of peripheral circulatory collapse. The former classification was indicated because the type of trauma may be, in a given case, a more important factor than the circulatory status in deciding when surgery should be done.

First, there are the wounded with trauma and hemorrhage as the underlying causes of the failing peripheral circulation. This group includes many combinations of injuries. In the absence of active hemorrhage it is possible to restore and maintain a stable peripheral circulation in these patients when sufficient blood and plasma are given.

Second, in addition to trauma and hemorrhage, some of the wounded have the added factor of cardiorespiratory embarrassment. The necessity for correcting cardiorespiratory embarrassment cannot be stressed too strongly, since the cause or causes of inadequate oxygenation must be relieved before the heart can be expected to respond favorably to injections of plasma or blood.

Third, there is the group of wounded with trauma and hemorrhage plus infectious or chemical contaminations. The contamination may be in the peritoneal (Case 1), or the pleural cavities, as well as in grossly macerated tissue. The men in this group, even in the absence of continued hemorrhage, usually respond sluggishly to transfusions and require large volumes of blood and plasma.

The circulatory status was judged on the basis of the admission blood pressure. The following subdivisions were adopted: (a) casualties with a blood pressure in excess of 90 mm. Hg, in whom peripheral circulatory failure was impending; (b) those with a systolic blood pressure of 90 mm. Hg and below; and last (c) those with an absent auscultatory blood pressure. It was appreciated that an absence of the auscultatory pressure in the arm is not an index of the pressure existing in the cardiopulmonary system. An absent auscultatory, or a 0/0 blood pressure, is a grave omen in itself, since one cannot deter-

mine for what interval of time the patient has had this degree of peripheral failure. Immediate prognosis in patients, especially those with a 0/0 blood pressure, we found was dependent on the response of the systolic pressure to intravenous injections of blood or plasma. As long as a 0/0 blood pressure was restored to the supposed normal level (100 mm. Hg or more) with infusions of 500 to 1,500 c.c. of blood, the response was considered good and the immediate prognosis favorable.

BLOOD PRESSURE IN THE NONTRANSPORTABLE CASUALTY

After the number and types of wounds were noted and the possibility of active hemorrhage was considered, the blood pressure readings, in conjunction with the pulse and the respirations, served as the most reliable guide for replacement therapy. In spite of the acknowledged importance of the blood pressure readings, they were misleading in some instances. In casualties with traumatic amputations and in those with extensive soft tissue damage of the thigh and buttock, the blood pressure was often maintained around 100 mm. Hg from three to eight hours after wounding. When such patients were subjected to surgery without the supportive measure of 500 to 1,000 c.c. of blood, peripheral circulatory collapse frequently occurred during anesthesia or surgery. Patients with chest and abdominal wounds were known on occasion to react in a similar manner.

Patients arriving at field hospitals with records of having had plasma but without blood pressure recordings must be observed very carefully before any conclusions are reached concerning the stability of the peripheral pressure. One should know, in these cases, the initial pressure, how the pressure responded to plasma, and the ability of the circulation to maintain a stable peripheral pressure.

Auscultatory blood pressures have been observed to disappear in one of two ways. A systolic pressure around 100 mm. Hg may abruptly begin to decline and become inaudible in five to fifteen minutes after turning the patient preoperatively or during surgery. In other instances, the systolic pressure may maintain a level of around 90 mm. Hg and may be definitely recorded at this level while the sounds gradually diminish in intensity and tend to fade away. This latter finding is most often observed in the immediate postoperative period and is an ominous sign. When this observation is made we feel that plasma or blood is indicated.

An absence of the auscultatory sounds in the antecubital area is sometimes noted on early inspiration when the systolic pressure is first recorded and for the next 4 to 8 mm. Hg thereafter. This finding is much more frequent before and during surgery than in the convalescent period. It is also more frequently observed in individuals whose systolic pressure is 90 mm. Hg or above. The respiratory influence upon the systolic pressure preoperatively and during surgery seemed to be associated with an unstable peripheral pressure.

In Table I, twenty cases are tabulated to show the drop in systolic pressure which occurred during the course of treatment.

Out of this group of twenty cases only the patients in Cases 1, 5, and 7 had active bleeding during surgery. Six patients (Cases 1, 6, 7, 9, 10, and 11) developed peripheral failure postoperatively. A decline in systolic pressure which occurred during surgery was quickly observed and treated with added injections of blood or plasma. Peripheral circulatory failure postoperatively is likely to be missed during extremely busy periods unless a definite effort is

TABLE I. PATIENTS SHOWING DROPS IN SYSTOLIC PRESSURE DURING THE COURSE OF TREATMENT

DIAGNOSIS	PLASMA BEFORE ADM. (C.C.)	B.P. UPON ADM.	THERAPY BEFORE DROP		DROP IN SYSTOLIC B.P.	DROP OCCURRED DURING	THERAPY AFTER DROP		B.P. AFTER THERAPY
			BLOOD	IN B.P. (C.C.)			SYSTOLIC B.P. (C.C.)	CRYST.	
1. Ext. wds.*	250	80/50	1,800	-	130 to 80	Postop.	1,000	1,000	138/86
2. Chest and ext. wds.†	750	86/74	500	500	106 to 85	Surgery	-	1,000	120/70
3. Ext. wds.	500	60/44	2,000	250	140 to 70	Surgery	2,000	-	?
4. Sucking chest wd.	1,000	75/40	500	500	110 to 80	Anesthesia	500	2,000	?
5. Laceration of carotid artery*	None	120/55	-	-	110 to 0	Surgery	2,500	1,000	?
6. Penetrating wd., abd.	500	62/?	4,000	1,000	124 to 0	Postop.	-	1,750	120/80
7. Chest and abd. wds.	None	100/80	1,000	500	132 to 0	Postop.	500	1,250	110/70
8. Chest and ext. wds.	None	35/0	1,500	500	130 to 82	Surgery	1,500	2,000	90/70
9. Ext. wds.	250	60/50	1,500	-	90 to 70	Postop.	-	500	100/58
10. Thigh laceration	1,250	80/50	2,500	-	90 to 0	Postop.	1,000	1,000	98/60
11. Chest and abd. wds.†	500	110/70	3,000	-	70 to 30	Postop.	-	750	70/?
12. Chest and abd. wds.	1,250	60/30	2,500	-	105 to 70	Surgery	1,000	-	?
13. Ext. wds.	2,500	50/30	3,000	-	110 to 40	Surgery	3,000	-	100/60
14. Laceration of femoral artery	1,250	80/58	1,500	-	130 to 64	Anesthesia	-	2,000	118/80
15. Chest and abd. wds.	None	80/70	1,000	-	125 to 88	Anesthesia	500	-	?
16. Sucking chest wds.	1,000	60/40	1,500	-	118 to 0	Surgery	500	500	82/60
17. Chest and abd. wds.	500	70/50	950	500	110 to 80	Surgery	1,500	500	100/70
18. Sucking chest wd.†	500	0/0	1,000	-	108 to 65	Preop.	1,000	-	100/40
19. Sucking chest wds.	None	90/30	1,500	500	92 to 66	Anesthesia	1,000	500	100/60
20. Traumatic amputation of leg†	None	148/100	1,400	1,000	125 to 84	Surgery	500	-	98/70

Wds., Wounds.

Ext., Extremity.

Abd., Abdominal.

B.P.? Blood pressure not recorded.

*Patients with active bleeding during surgery.

†Died.

made to follow hourly blood pressure fluctuations for at least the first six hours after surgery. Many factors such as deep anesthesia, continuing hemorrhage, and certain intrathoracic injuries are known to cause lowering of the blood pressure, but in the seriously injured, inadequate replacement therapy was felt to be the most frequent cause for a break in peripheral circulatory compensation. It has been repeatedly demonstrated that a failing peripheral pressure can, in many instances, be restored and maintained with added injections of blood and plasma. In view of the frequency with which drops in systolic pressure occur during the course of treatment, we believe that replacement therapy is inadequate unless an added 500 to 1,000 c.c. of blood are given after the assumed normal level (100 mm. Hg) is attained. Replacement therapy, therefore, does not stop in the resuscitation tent, but is continued during surgery and is usually necessary for the first six hours postoperatively (see Case 1).

During surgery, when drops of blood pressure develop as the blood is being injected, the drop is relieved by increasing the volume of flow by gravity or pressure depending on the degree of the drop. Injecting more blood or plasma at such a time is the most effective means of overcoming the developing peripheral collapse if it is amenable at all to intravenous therapy. Once the systolic pressure is restored to 70 mm. Hg a definite attempt is made by the anesthetist to determine whether generalized fine moist râles have developed during the course of injection. In the event of moist râles, the rate of flow is so regulated that a level of 80 mm. Hg is, if possible, maintained and the level of 100 mm. exceeded only after several hours.⁵

CLINICAL OBSERVATIONS

Patients with abdominal and extremity injuries with an admission 0/0 blood pressure which failed to respond to transfusions were usually conscious until shortly before they died. Patients with chest injuries and an associated anoxemia may be restless or at times unconscious, even when the systolic pressure is 70 mm. of Hg or more. Head injuries, as a group, did not present the peripheral circulatory collapse that other types of injuries tended toward, although the very severe head injuries did show fluctuations in pulse and blood pressure. Unconsciousness, of course, was common in this last group. As is well known, the color of the skin is influenced by the external temperature, the severity of the hemorrhage, and the presence or absence of respiratory embarrassment. Patients with hemopneumothorax were cyanotic if they had not lost too much blood; otherwise they were pale. Those with massive or recurrent hemorrhage whose blood pressure was supported with repeated injections of plasma had a waxy yellow skin. In our experience, including the wounded with waxy yellow skins, the color of the skin and lips was not reliable in evaluating the circulatory status of the patient. Red lips with an absent auscultatory blood pressure and pale lips with a systolic pressure above 100 mm. Hg have been observed. The majority of the casualties treated were cold and wet, some had oral temperatures as low as 93° F. Blood stored in the icebox was routinely injected. Sweating was rare in the patients observed in this study.

The pulse was usually rapid and feeble while in other instances it was slightly accelerated in the presence of peripheral failure.¹ Unless the radial pulse was absent or in excess of 140 beats per minute, the circulatory status was difficult to evaluate from the pulse rate. Frequently, a pulse rate of 140 fails to diminish with transfusions in the presence of a rising blood pressure. When the surgical condition permits, in such a case a delay of one-half to one

hour with added transfusions is helpful. An increase in the radial pulse rate was not infrequent during resuscitation (see Case 3). A pulse deficit of 3 to 6 per minute was not uncommon in patients with a systolic pressure of 70 mm. Hg. In our experience the radial pulse volume was a far better index of the condition of the peripheral circulation than was the rate.

As has been previously noted by others, the veins in the extremities may be so diminished in caliber that they are no longer discernible. Sometimes it is impossible to insert a needle into a vein, because, in addition to the decreased diameter, active spasm of the venous wall occurs. In other instances, after the saphenous vein is cannulated, the resistance to the flow of blood can be so pronounced that gravity will not suffice. Cold blood frequently induces some venous spasm and a decrease in the rate of flow. At times cold blood may actually stop flowing when suspended four feet above the patient, thus necessitating positive pressure as recommended by the British Transfusion School.¹

HEMORRHAGE IN THE NONTRANSPORTABLE CASUALTY

Trauma and hemorrhage were, in this group, so associated and so closely interrelated in their influence upon the circulation that it was difficult to think of one without considering the other. Early in this study it became evident that the patients had lost much more blood than one might have thought. Surgical intervention for active bleeding, however, was rarely necessary on admission, since bleeding had usually stopped spontaneously. Even though it was not possible to estimate the volume of blood lost prior to admission, it was felt that this loss was appreciable. In patients admitted to the field hospital, hemorrhage from extremity wounds was often excessive. The proper application of the tourniquet in these cases cannot be stressed too strongly.² In abdominal injuries hemorrhages of 1,000 to 1,500 c.c. of blood were common.³ In injuries of the chest as much as 2,000 c.c. of blood may be recovered from the pleural cavity where partial or complete hemostasis had been established before surgery. Continued minimal bleeding was observed during surgery from mesenteric and intercostal vessels, and in rupture of the spleen, liver, and kidneys.

ROUTINE ADOPTED FOR THE TREATMENT OF WOUND SHOCK

Any generalizations advocated for the treatment of patients in shock have exceptions. In many of the casualties 1,000 c.c. of blood or plasma alone can no longer be considered sufficient resuscitation. The routine described here sufficed for the majority of the cases. The exceptions required consideration in deciding what volume of blood should be given, the speed of injection, and whether surgery should wait until a satisfactory compensation was attained.

The admission blood pressure served as a criterion for the speed with which resuscitation was started. Those with the lowest pressure received treatment first.

Individuals suspected of impending peripheral failure with an admission pressure of 90 mm. Hg or more were given 1,000 c.c. of blood in one to two hours' time by gravity, regardless of whether or not plasma had been given previously. Patients with traumatic leg amputations were most frequently in this group.

Casualties with a pressure of 90 mm. Hg and less were given blood at such a rate that 500 c.c. were administered in approximately thirty minutes. The volume of blood which patients in this group obtained depended on the response of the blood pressure, the pulse changes, and the patient's general condition.

Casualties with a 0/0 blood pressure were considered to be in advanced peripheral circulatory collapse. Therefore, vigorous resuscitation was administered. These casualties usually required 2,000 c.c. of blood and plasma. However, total volumes (preoperatively and during surgery) of 4,000 to 5,000 c.c. were not uncommon (see Table II). Furthermore, should the patient lose say 500 c.c. of blood in a short time during surgery, the replacement of this volume in a similar time interval was desirable. For these reasons patients with a 0/0 blood pressure had cannulae routinely inserted and tied into the vein. With the cannulae intact the blood was forced under pressure into the vein so that 500 c.c. were injected in five to ten minutes. Blood was injected at this rate as long as the systolic pressure remained below 70 mm. Hg. Once the systolic pressure attained 70 mm. Hg the rate of infusion was decreased so that 500 c.c. required around thirty minutes. In the absence of external bleeding, when the blood pressure failed to attain 100 mm. Hg after 1,500 c.c. of blood had been given rapidly, the patient's condition was re-evaluated in conjunction with the surgeon. Patients who failed to respond to 2,000 c.c. of blood injected rapidly were found to have continuing hemorrhage or some other factor producing the peripheral collapse. Experience showed that in such cases nothing was gained by delaying surgery. Therefore, most of these cases were recommended for operation in the absence of a satisfactory peripheral pressure (see Case 2).

Patients with chest injuries who exhibit peripheral failure may present added difficulties in resuscitation. Most casualties with chest injuries had systolic pressures in excess of 70 mm. Hg on arrival. When cardiorespiratory embarrassment is present, injection of blood or plasma should not exceed the rate of 500 c.c. in thirty minutes until the factors of hemothorax, pneumothorax, blood or mucus in the trachea, and pain associated with chest wall defects are ruled out or treated.⁶ A rapid respiration, commonly with a shallow excursion, was usually evident in the presence of cardiorespiratory embarrassment. Failure to relieve the causes of cardiorespiratory embarrassment can cause an unsatisfactory response to intravenous therapy (see Case 3), may prolong restlessness or unconsciousness if present, and may result in death.

No heat was applied to the patients. The clothes were removed and the wounded were placed between dry blankets. Intranasal oxygen was reserved for the cyanotic patients, for those with chest injuries and dyspnea or tachypnea, and for those who failed to respond satisfactorily to injections of blood or plasma. The casualties were not placed in the shock position because when vigorous intravenous resuscitation was done this did not seem necessary. Others may feel differently about this point, but such was our experience.

In many of the casualties the skin color and skin circulation were modified by injections of cold blood, and by physical and x-ray examinations in cold tents, all of which prevented the casualty from becoming warm until long after surgery. Due to these facts much stress was placed on systolic blood pressure and the pulse findings and it was felt that a systolic pressure restored to at least 100 mm. Hg allowed for greater safety. Individuals with a satisfactory response were sent to the x-ray division after the systolic pressure attained 100 mm. Hg, at which time the rate of infusion was slowed in accordance with how much blood was required. Those with unsatisfactory responses were seen in consultation with the surgeon and it was often found advisable to limit the examination to one or two x-ray exposures. With this policy it was to reduce the incidence of drops in systolic pressure preoperatively.

TABLE II. RESUSCITATION OF WOUNDED WITH 0/0 BLOOD PRESSURE ON ADMISSION

DIAGNOSIS	PLASMA BEFORE ADM. (C.C.)	B.P. UPON ADM.	PREOPERATIVE		TIME PREOP. HR. MIN.	RESUSCITATION IN SURGERY		POSTOP. THERAPY		B.P. AFTER THERAPY	
			BLOOD (C.C.)	PLASMA (C.C.)		B.P.	BLOOD	PLASMA G.C.	CRYST. G.C.		
1. Pen. wd. abd.*	None	0/0	2,000	500	2 10	60/40	1,000	—	—	98/?	
2. Ext. wds.	?	0/0	1,500	—	5 25	100/70	1,500	—	750	100/80	
3. Ext. wds.*	None	0/0	2,000	500	4 45	100/80	500	1,250	—	100/80	
4. Traumatic leg amputation	250	0/0	1,000	250	?	112/60	—	—	—	?	
5. Laceration of femoral artery	250	0/0	2,500	500	2 50	90/60	500	—	1,250	154/?	
6. Ext. wds.†	1,000	0/0	2,000	—	4 45	104/80	—	—	750	0/0	
7. Pen. wd. abd.	None	0/0	3,000	—	4 35	112/72	—	—	500	?	
8. Pen. wd. abd.†	500	0/0	3,000	—	6 55	82/60	1,000	250	—	?	
9. Ext. wds.	750	0/0	4,500	1,250	21 15	95/75	—	—	—	110/76	
10. Ext. wds.	500	0/0	5,000	—	13 30	?	—	—	—	128/84	
11. Ext. wds.	500	0/0	1,500	—	4 05	130/85	—	500	—	?	
12. Cord injury†	None	0/0	500	1,250	2 02	Died before surgery with peripheral failure					?
13. Laceration of femoral artery	1,000	0/0	1,500	—	0 15	100/68	—	—	130/70	?	
14. Pen. wd. abd.	None	0/0	1,000	—	2 50	90/58	2,000	—	76/42	3,000	
15. Pen. wd. abd.†	250	0/0	1,000	500	1 55	95/60	1,000	500	95/?	1,000	
16. Chest wd.	None	0/0	1,000	—	1 35	84/40	1,000	—	70/34	?	
17. Chest wall wd.	200	0/0	1,000	500	?	100/?	—	1,000	95/50	0/0	
18. Chest wd.†	500	0/0	1,500	—	2 15	65/55	—	—	80/50	?	
19. Pen. wd. abd.†	500	0/0	3,500	—	1 55	84/44	2,500	—	84/?	100/40	
20. Traumatic amputation of leg	None	0/0	1,000	1,000	2 10	104/70	2,000	—	110/?	60/40	
Pen., Penetrating.										150/90	

Pen. Penetrating.

Wds. Wounds.

Abd., Of the abdomen.

Ext., Extremity.

B.P., Blood pressure not recorded.

*Patients with active bleeding during surgery.

†Died.

In Table II, twenty cases in which the patients had 0/0 blood pressure, picked at random and having been operated upon and treated by various surgeons, are recorded with pertinent data pertaining to preoperative, operative, and postoperative treatment. Some of these patients were treated as just prescribed; others were not. Table II should be of interest in that it presents a cross-section picture of the problem of dealing with the casualty admitted with 0/0 blood pressure.

In twelve of the cases, plasma given at forward stations, although definitely helpful, was incapable of maintaining the peripheral pressure during evacuation. Of the seven patients who died after surgery, four (Cases 8, 12, 18, and 19) responded poorly to injections of blood and plasma. Circulatory compensation was restored preoperatively in nine (Cases 2, 3, 4, 6, 7, 11, 13, 17, and 20) of the twenty cases. Five of these nine required more blood or plasma during surgery to bolster a declining systolic pressure. One patient³ in this group had active bleeding at the time of operation. Nine had surgery started before the systolic pressure attained 100 mm. Hg. Of these nine the response to 2,000 c.c. or more of blood and plasma was poor in five (Cases 1, 5, 8, 18, and 19), therefore, surgery was recommended immediately. One patient (Case 9) had a satisfactory response, but with the lapse of time the systolic pressure began to drop slowly. Some patients (Cases 14, 15, and 16) had satisfactory blood pressure responses preoperatively; however, surgery was initiated before the desired peripheral pressure was attained. In these three cases we feel that sufficient blood was not given in the immediate postoperative period. One patient (Case 12) who had a perforation of the cervical cord failed to respond to intravenous injections and died before surgery.

The time spent in the resuscitation tent varied from fifteen minutes to twenty-one hours, fifteen minutes. The patients who waited longer than four hours did so during unusual periods of heavy casualty admissions.

In Table II is shown how variable was the response to intravenous infusions. In rare cases a 0/0 blood pressure was elevated to the 100 mm. level with 500 c.c. of blood. Commonly, the response was slower so that from 1,000 to 1,500 c.c. of blood and plasma were necessary (Cases 2 and 4). In some the systolic pressure did not exceed the 100 mm. level until 2,000 c.c. of blood were injected (Case 6). Finally there were others failing to exceed the 100 mm. level even after administration of 2,500 c.c. of blood (Cases 5, 8, and 19).

DISCUSSION

It was not felt that issue should be taken with the now existing confusing nomenclature pertaining to "shock." For the purpose of clarity, it was felt that a description of the casualty as recommended by Grant⁷ was more desirable until the moot aspects of terminology are settled. How much influence the factors of pain, dehydration, and cold exert on the peripheral circulation in the wounded remains undetermined. With time, however, we began to feel that simple blood loss prior to and during surgery was responsible for most of the peripheral failure. The response of the blood pressure and pulse to infusions of blood and plasma remained the principal guide, first for the volume to be injected, and second as to when surgery should be instituted.

Early in this study, even though adequate quantities of whole blood were not available, we realized that a failing peripheral circulation could not be effectively restored and maintained with plasma alone. It was soon found that there were some patients who lost excessive blood in whom plasma produce

only a temporary elevation of the peripheral pressure. The decreased oxygen-carrying capacity of the blood in patients with excessive hemorrhage and the frequency of alarming anemias with hematocrit reductions of from 20 to 60 per cent of normal during the first week postoperatively⁴ made us feel that a mere restoration of circulatory volume with plasma was not enough. Although facilities for determining blood volumes were not available to us at the time, one of us (J. J. L.) was able, while at Anzio, to make hematocrit determinations. These studies then and since have proved invaluable guides in directing intravenous therapy and in evaluating the patient's physical status postoperatively.

In our opinion, nontransportable patients requiring resuscitation should receive whole blood. It is impracticable under military conditions to furnish blood forward of the first priority surgical hospital units adjacent to division clearing stations. At present, plasma is used to support a failing peripheral pressure until such a time when whole blood can be administered.

It may appear that blood was injected too rapidly, especially into casualties who arrived with a 0/0 pressure. Rapid injection of blood was adopted for two reasons: First, those who did not respond to 1,500 c.c. of blood were sent to surgery more quickly than were those who did respond to this amount. Second, it was felt that the patient's chance of survival was better the sooner the systolic pressure rose above 70 mm. Hg.

With improvements in resuscitation and the availability of whole blood our attention was focused on the occurrence of postoperative uremia. The possible role of blood in relation to this syndrome was considered. From 2 to 3 per cent of the casualties treated in field hospitals developed this complication. The oliguria appeared within ten to eighteen hours postoperatively. In giving serious consideration to the possible role of blood in the production of postoperative oliguria, the question arises as to whether it would be preferable to carry a patient through the preoperative, operative, and immediate postoperative courses on minimal rather than generous quantities of blood. Some feel strongly that this more conservative regimen should be adopted. An objection offered by others is that a risk is encountered in giving, unknowingly, not enough blood. With further studies of postoperative uremia, a satisfactory index, we trust, will be arrived at. We have practiced, to date, the giving of generous rather than minimal quantities of blood.

The factor of hydration in these casualties warrants consideration. We have found no gross clinical evidence of dehydration as judged by decreased skin turgor. However, it is known that in many instances there was a limited intake of water before injury. Water was purposely denied in abdominal wounds. Some of the wounded had not had water for thirty-six hours. Thirst was a frequent and a constant complaint. Postoperatively, there was often a lag period in urinary excretion of from six to ten hours. It would seem reasonable, therefore, to inject from 1,000 to 2,000 c.c. of 5 per cent glucose intravenously as soon as the peripheral pressure is restored and rendered stable with injections of plasma and blood. This is recommended with the hope that urinary excretion will be stimulated as quickly as possible following surgery.

CASE REPORTS

CASE 1.—A white adult man was injured by hand grenade fragments before 8:15 P.M., June 10, 1944. The patient's wounds were bandaged and he was evacuated to the field hospital where he arrived at 8:45 P.M. Superficial examination revealed penetrating wounds of

the left side of the chest and the left shoulder with a compound comminuted fracture of the middle third of the left humerus. There was a penetrating wound of the abdomen, as well as the right knee with a compound comminuted fracture of the patella. In addition, there were lacerating wounds of the chin, the right supraorbital and malar areas, the right third toe, and the left elbow. The patient was conscious and the admission pressure was 100/80, while the pulse rate was 100. He was immediately given two bottles of dry plasma dissolved in 300 c.c. of distilled water. Five minutes later the blood pressure was 132/88 with a pulse rate of 96. At 10:20 P.M., the first transfusion of 500 c.c. of blood was begun. Shortly thereafter, the patient was given 1/100 gr. of atropine sulfate. Surgery was performed at 11:10 P.M. under endotracheal ether oxygen anesthesia. During surgery the following defects were observed and corrected: Bleeding intercostal second left interspace was ligated, foreign body was not found. Clavicular wound was débrided and foreign body was removed. At exploratory laparotomy 10 cm. of small intestine including perforations were resected and an end-to-end anastomoses was performed. Three perforations of the lowermost portion of the rectosigmoid were closed and a proximal loop sigmoid colostomy was constructed and exteriorized through a left lower quadrant gridiron incision. Estimated blood loss was 500 c.c. from the intercostal artery and 500 c.c. from the intra-abdominal injuries. The lacerations of the right knee, chin, and the orbital areas were then débrided. Surgery was completed at 4:10 A.M. During the operation the patient received 500 c.c. of blood and 1 unit of plasma. The blood pressure at the termination of the operation was 100/75, while the pulse rate was 112. Five hours, five minutes following surgery, the radial pulse was absent, and the pressure was inaudible. The patient was conscious. The skin was dry and pale. One unit of plasma was started immediately. Fifteen minutes later the patient became restless and began to shiver. At 9:40 A.M., dried plasma (two bottles), dissolved in distilled water (300 c.c.), was started. By 10:10 A.M. the blood pressure had risen to 110/70. After this, a 500 c.c. transfusion of blood and another 500 c.c. of plasma were given. In the afternoon of the same day the patient received 2,000 c.c. of saline glucose mixture. Ten days later the patient was comfortable and convalescing satisfactorily.

Comments.—This patient with extensive trauma arrived at the field hospital without previous resuscitation therapy. As a supportive measure, 2 units of plasma and 500 c.c. of blood were given preoperatively. During surgery another 500 c.c. of blood and 1 unit of plasma were found to be adequate to maintain the systolic pressure throughout the operation. Following surgery, the patient developed severe peripheral collapse which responded satisfactorily to added infusions of plasma and blood. In retrospect, it would have been preferable to give more blood during the operation.

CASE 2.—A white adult man was injured by a 25-caliber bullet shortly before 5:00 P.M., March 16, 1944. He was given morphine, $\frac{1}{2}$ gr., prior to admission to the field hospital to which he was admitted at 5:45 P.M. on the same day. Examination revealed that the bullet entered the left upper quadrant and lodged in the subcutaneous tissues of the right lower quadrant. The skin was cold and pale. The patient was lethargic and sweating about the lips. The radial pulse was imperceptible, and the blood pressure was inaudible. The carotid pulse rate was 112. A transfusion of 100 c.c. of serum albumin was immediately started which was followed in five minutes with 500 c.c. of whole blood. Due to the patient's severe peripheral failure, intranasal oxygen was also started. By 6:05 P.M. the blood pressure had risen to 60/40, at which time a second blood transfusion was started. Twenty minutes later a third blood transfusion was begun. At 7:50 P.M. the blood pressure and the general appearance had not improved, so the patient was scheduled for early surgery. Ten minutes later the patient was given atropine sulfate, 1/100 gr., and a fourth transfusion of blood was started. In spite of the continuous injection of blood, the blood pressure remained unchanged until operation. Surgery was performed at 8:30 P.M., March 16, 1944, by one of us (J. M. M.). The injuries observed and the surgery performed were as follows: Active bleeding was controlled from small arteries and a large vein in the mesentery of the transverse colon. Three perforations of the jejunum were closed. One perforation of the transverse colon was exteriorized. Surgery was completed at 9:30 P.M. During the operation the patient received 1,000 c.c. of blood, 500 c.c. of plasma, and 1,000 c.c. of saline dextrose. At the termination of the operation the pressure was 70/40 and the radial pulse was 120. The patient was taken to the postoperative ward where intranasal oxygen and a Wangenstein suction were continued, and an added 2,000 c.c. of saline dextrose injected before midnight. The next morning the systolic pressure was 98 mm. Hg. the pulse was feeble with a rate of 140, while the respiratory rate was 28. During the day the patient was given 500 c.c. of blood, 500 c.c. of plasma, and 3,000 c.c. of saline dextrose.

Comment.—The patient arrived in an advanced state of peripheral failure. Since the pressure did not respond satisfactorily to 2,000 c.c. of blood, surgery was instituted early in an effort to eliminate some of the factors which may have been supporting peripheral failure, it being understood that resuscitation would continue during and after surgery. This patient was evacuated three weeks after surgery in good condition.

CASE 3.—A white adult man was injured by shell fragments shortly before 11:30 A.M., Feb. 9, 1944. Treatment received prior to admission to the field hospital included 3 units of plasma and 1 c.c. of tetanus toxoid. He was admitted at 2:50 P.M., the same day. Examination revealed a posterior chest wall wound 6 by 8 inches which was "sucking." There was bilateral paralysis of the lower extremities and a penetrating wound of the left leg. The systolic pressure was 70 mm. of Hg. The patient was pale, warm, and restless. He was lying on the abdomen and he complained of difficult breathing. The respiratory excursions were shallow with a rapid rate of 30. The radial pulse was feeble, the rate was 96. A transfusion of blood was started and injected slowly. By 4:05 P.M. the pressure had risen to 122/30, the respirations decreased to 22, but the pulse rate rose to 128. The patient still complained of difficult breathing, therefore, he was rolled over on his side. At this time 500 c.c. of plasma were started. At 5:25 P.M. the patient began to develop cyanosis; intra-nasal oxygen was started. The pressure at this time had dropped to 94/30. Pneumothorax was diagnosed, the right pleural cavity was aspirated, and 1,200 c.c. of air were recovered. Following the aspiration of air, the restlessness diminished, the cyanosis disappeared, and breathing became deeper and less painful. A second transfusion of 500 c.c. of plasma was started after which the pressure maintained a stable level. Surgery was performed at 6:50 P.M. under intratracheal ether oxygen anesthesia. Surgery performed was as follows: The posterior chest wound was débrided. The spine of the eleventh dorsal vertebra had a compound fracture. A laminectomy of the eleventh dorsal vertebra was performed. More air was aspirated from the right pleural cavity. Surgery was terminated at 9:05 P.M. During the operation the patient was given 1,000 c.c. of blood. At the end of the operation the pressure was 105/45 with a pulse rate of 82 and a respiratory rate of 22. On the following day the patient was comfortable. There was an absence of sense perception to the level of the umbilicus. The pulse rate was 84 and the respiratory rate was 18. After a period of two weeks the patient was evacuated to the rear.

Comment.—This patient had difficult breathing which became progressively worse with the appearance of cyanosis and increased restlessness during resuscitation. Following the aspiration of air from the pleural cavity the improvement was rapid and dramatic.

SUMMARY

1. The nontransportable casualty is defined.
2. An arbitrary classification of casualties based on trauma and circulatory status is suggested.
3. Hemorrhage is probably the most significant factor in the casuation of peripheral circulatory failure, since the change of appearance of the patient and the restoration of the systolic pressure is dramatic in most instances following the injection of adequate quantities of whole blood.
4. Other common factors in the production of peripheral circulatory collapse in the wounded are infection and cardiorespiratory embarrassment.
5. During resuscitation in the preoperative and surgical phases of treatment the systolic pressure may drop while blood or plasma is being injected. At such times, depending on the degree of drop, the rate of infusion should be accelerated.
6. Individuals verging on circulatory collapse or those whose blood pressure is restored to the 100 mm. Hg should have an added 500 to 1,000 c.c. of blood either preoperatively or during surgery before resuscitation is considered adequate.
7. Three cases are reported to illustrate specific points.

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THE PERITONEAL ABSORPTION OF PENICILLIN

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A KNOWLEDGE of the rate of absorption of penicillin through the normal, noninflammatory peritoneum should be regarded as a necessary prerequisite for the evaluation of this drug in abdominal surgery. In a recent study of a small number of patients, Green and Altire-Weber¹ found that the intraperitoneal instillation of penicillin was followed by significant bacteriostatic concentrations of the antibiotic in the blood. They therefore concluded that penicillin was of prophylactic value against infections of abdominal origin.

In the present investigation the rate of absorption of penicillin through the normal human peritoneum was determined in a series of twenty-two patients subjected to operation for hernial repair. Penicillin in solution was instilled into the peritoneal cavity by rubber catheter through the hernial sac just prior to its ligation. In each case, 100,000 Oxford units of penicillin, dissolved either in 100 c.c. of plasma or in normal saline solution, were injected. In addition to an initial preoperative blood sample, 5 c.c. of blood were drawn at intervals of one hour for a period of seven hours. The concentration of penicillin in the serum was determined quantitatively by the agar cup method of Fleming.² The test organism, a penicillin-sensitive *Staphylococcus aureus* "H," was seeded through the agar plate. Parallel determinations were made frequently by Rammelkamp's serial dilution method. Also, the patients were observed carefully for clinical evidence of penicillin sensitivity or toxicity.

Penicillin in plasma or penicillin in saline solution was absorbed readily through the peritoneum (Tables I and II). The highest concentration of penicillin appeared in the first blood sample one hour after instillation of the drug in the peritoneal cavity. Its average value was found to be about 1.2 Oxford units per cubic centimeter of serum. Thereafter, there was a progressive decline in the concentration of penicillin in the blood. In the final samples six or seven hours after intraperitoneal injection, penicillin was not estimable quantitatively. Clinically, the patients tolerated well the presence of penicillin solution in the abdomen. In this series of patients there were no manifestations of sensitivity or toxicity.

The absorption of penicillin into the blood stream from the peritoneum was maintained over a period of three to five hours, during which time its concentration in the blood was potentially bacteriostatic. Nevertheless, the rate of absorption of penicillin was such as to indicate that the progressively decreasing

TABLE I. PENICILLIN IN SALINE

	1	2	3	4	5	6	7
1	0.0	1.2	1.0	1.0	0.8	0.5	0.1
2	0.0	2.4	2.0	1.0	0.7	0.6	0.2
3	0.0	2.0	2.0	2.0	0.8	0.7	0.4
4	0.0	1.0	0.8	0.5	0.5	0.5	0.2
5	0.0	2.0	1.3	1.0	0.8	0.0	0.0
6	0.0	2.0	1.0	1.0	0.8	0.0	0.0
7	0.0	2.0	2.0	1.0	0.8	0.0	0.0
8	0.0	1.2	0.8	0.5	0.5	0.5	0.1
9	0.0	1.5	1.0	0.4	0.1	0.0	0.0
10	0.0	0.4	0.8	0.6	0.3	0.1	0.0
11	0.0	1.3	0.7	0.4	0.2	0.1	0.0
Average value	0.0	1.5	1.2	0.8	0.5	0.2	0.09

TABLE II. PENICILLIN IN PLASMA

	1	2	3	4	5	6	7
1	0.0	1.2	1.0	0.5	0.2	0.1	0.0
2	0.0	0.8	0.5	0.2	0.0	0.0	0.1
3	0.0	1.4	1.0	0.8	0.5	0.5	0.1
4	0.0	1.2	0.9	0.9	0.6	0.4	0.1
5	0.0	1.4	1.0	0.7	0.4	0.2	0.0
6	0.0	0.8	0.0	0.5	0.2	0.1	0.0
7	0.0	1.5	1.2	0.8	0.7	0.3	0.1
8	0.0	0.1	0.1	0.4	0.2	1.0	0.0
9	0.0	0.7	0.5	0.3	0.1	0.0	0.0
10	0.0	1.2	0.7	0.1	0.0	0.0	0.0
11	0.0	0.9	0.7	0.6	0.5	0.5	0.2
Average value	0.0	1.0	0.6	0.5	0.3	0.2	0.04

residuum of the drug in the peritoneal cavity was effectively locally also. Moreover, results of these experiments have confirmed Greene and Altire-Weber's¹ claim that penicillin in the blood via peritoneal absorption was more sustained than that obtained by the usual intravenous or intramuscular fractionation methods.

SUMMARY

The rate of absorption of penicillin through the peritoneum into the blood stream was studied in twenty-two normal patients. Penicillin appeared in significant quantities in the blood for a period of about five hours after its instillation in the abdomen.

The author acknowledges gratefully the technical assistance of Sergeant R. Paul.

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THE MOLDED BONE GRAFT

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THE use of bone as a contour-restoring substance to replace losses of bone has in the past had two drawbacks. The first has been difficulty in carving the bone graft to shape; the second has been difficulty in finding a simple method of immobilizing the graft. It is the purpose of this paper to describe a type of bone graft, namely, the molded bone graft, which overcomes these drawbacks, and also to demonstrate that in selected cases this method is the one of choice.

At the outset, I should like to make it clear that it is not my contention that the molded bone graft is suitable for *any* loss of bone. It must be used with caution in the region of the frontal sinus because of the possibility of infection via a patent frontonasal duct. I have not utilized this type of graft for losses of both the inner and outer table of the calvarium, but I can see no objection to its use in such cases provided tantalum foil is applied over the dura, and provided also that the through-and-through loss is not too great. The molded bone graft is not advocated for use in the nose, for here any minute irregularity would be too obvious. It is, further, not recommended for functional restoration of the mandible, where stress or strain will be placed upon the graft.

Although use of the molded bone graft is not intended to displace use of the tantalum plate in extensive defects, in small or moderate-sized defects the use of the molded bone graft is certainly simpler, easier, and quicker than the use of a tantalum plate, which requires tedious fitting. Furthermore, one is not troubled by the presence of serum, which frequently accumulates behind the plate. An additional advantage of the molded bone graft over tantalum is the fact that eventually the blood circulation grows up through the graft into the overlying skin, and the skin itself is, therefore, much more durable and less liable to break down than is skin over a tantalum plate.

In short, the molded bone graft is advocated only as a contour restoration. It is admirably suited to building up defects about the forehead, the frontal area, the glabellar region, the supraorbital and infraorbital ridges, the malar bone, the zygomatic arch, and the chin.

To date, fifteen grafts have been done by this method, and while in the earlier cases the cosmetic effect was not entirely satisfactory, in the later cases this technical defect has been surmounted. In none of the cases has there been infection or any other complication. The number of cases, the absence of complications, the facility with which the procedure may be carried out, the simplicity of the technique, and the highly satisfactory cosmetic results, all indicate in my opinion that the molded bone graft, *in selected cases*, is far superior to the ordinary bone graft, the cartilage graft, or the derma graft.

The superiority of the molded bone graft to the ordinary bone graft as a contour-restoring substance has already been indicated. In comparing the molded bone graft to costal cartilage as replacement for bone loss, one need merely point out the shortcomings of the latter material. Cartilage itself

difficult to carve. The diced cartilage graft circumvents this disadvantage, but does not produce so solid a result as does the molded bone graft. Ordinary costal cartilage grafts have a tendency to curl and warp, and although several methods have been described whereby this disadvantage may be controlled, the methods are not always successful. It is no more difficult to obtain the bone graft than it is to obtain costal cartilage, and, furthermore, after the bone graft has been removed, the patient does not have nearly as much pain in the donor site as when cartilage has been taken from the chest. The derma graft is subject to infection, does not produce as solid a result as bone, and tends to shrink.

In the final analysis, loss of bone is best replaced by bone, for to replace bone by cartilage or derma is certainly no improvement upon nature.

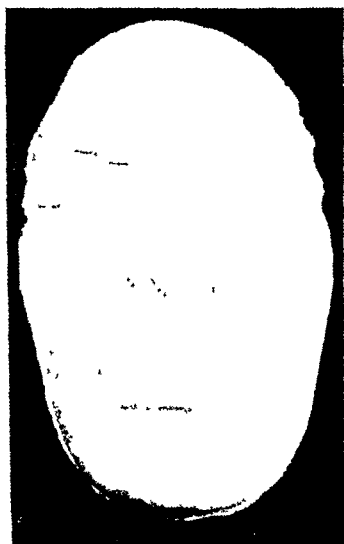


Fig. 1.



Fig. 2.



Fig. 3.

Fig. 1.—Simple plaster study model; this shows a depression of the glabellar region.

Fig. 2.—The plaster cast with the contour restored. Heavy wax is used for the purpose; the wax is stiff enough to resist molding.

Fig. 3.—The plaster cast with the mold or splint completed.

PLANNING THE OPERATION

The operative procedure must be painstakingly planned. Herein lies the difference between a highly satisfactory result and a mediocre one. The loss of contour should be thoroughly studied. Roentgenograms should always be taken, and the patient viewed from all angles. In losses of the forehead, the malar region, the glabella, or the supraorbital and infraorbital ridges, if the patient is placed prone upon the table and viewed from above and in back, the loss will become more evident, especially when the defective side is compared with the normal side. Palpation to determine the shape of the base of the defect should be carefully carried out.

If there is a history of osteomyelitis, the repair should not be undertaken until *at least* three months after the condition has been thoroughly and completely healed. Healing should be checked preoperatively by x-ray examination. The three-month interval is permissible in the event that penicillin is available. If it is not, at least six months should elapse. If this type of bone graft is attempted as early as three months after the cessation of bone drainage, a course of penicillin should be given prior to operation and thereafter as well. It may seem superfluous to point out that no attempt should be made to

insert a bone graft through a skin covering that is badly scarred or unstable, for to do so will certainly endanger the result.

A plaster study model should be prepared, and this should include not only the area of defect but the normal side as well, and as much of the face as possible (see Fig. 1). The restoration should be built up on this plaster cast in hard wax or in plaster (see Fig. 2). Plasticine, although it is more readily molded than are these other materials, is not suitable because of its soft consistency, for it will be necessary to form a metal splint over the restoration. The cast and restoration should be viewed from many angles, to make certain of the proper contour. The wax pattern may be tried on the patient.

Sheet lead approximately one thirty-second of an inch in thickness is used to form the mold or splint. A piece of the proper size is trimmed to approximate shape. The mold should extend well beyond the restored area, its periph-

Fig. 4.



Fig. 5.

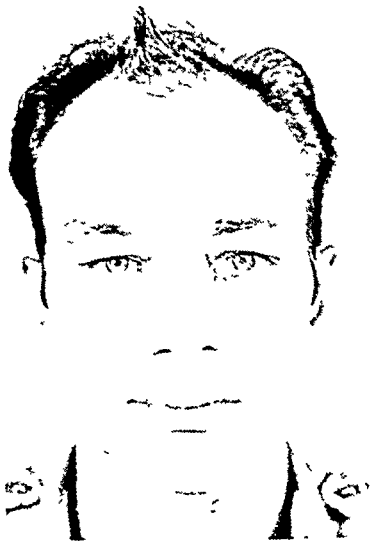


Fig. 6.

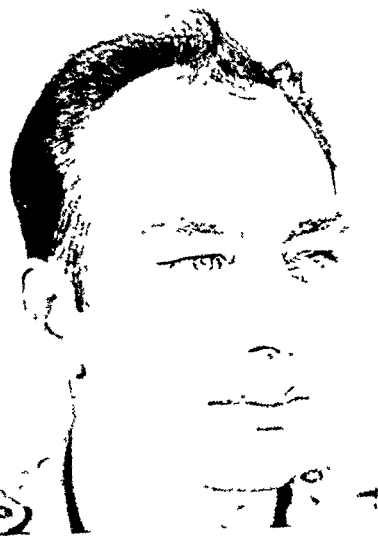


Fig. 7.

Fig 4—Depressed fracture of the glabellar region and root of the nose, the result of an airplane crash. Incision made through left eyebrow.

Fig 5—A three-quarter view of the same patient.

Fig 6—Four months postoperative.

Fig 7—Three-quarter view, four months postoperative.



Fig 8

Fig 9

Fig 10

Figs 8 9, and 10—Irrregular depression with loss of the outer table of the frontal bone the result of osteomyelitis

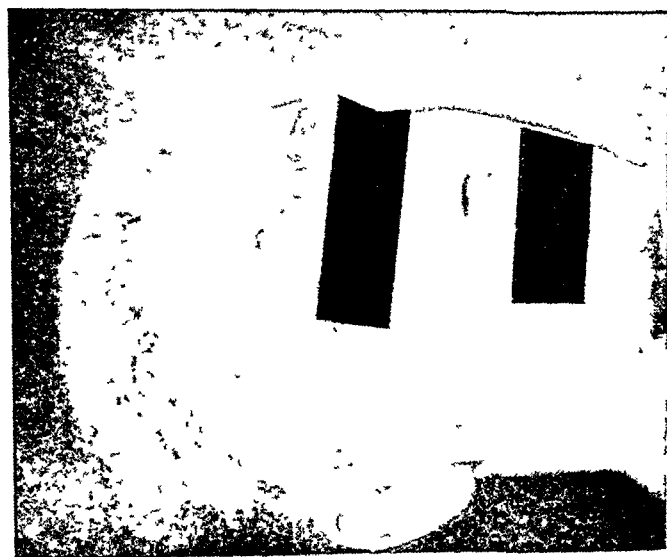


Fig. 11.



Fig. 12.

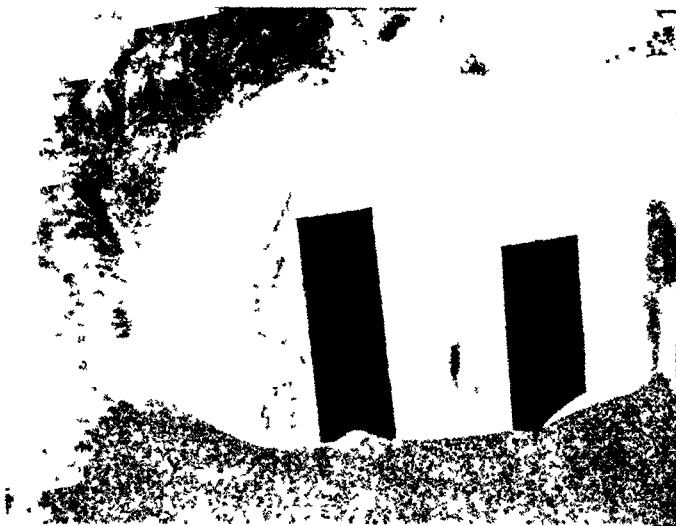


Fig. 13.

Figs 11, 12, and 13—Postoperative condition. This was one of the early cases (1912), and in this instance the thin shavings of cortical bone had not been used.

small, sharp bone saw will be sufficient to prepare the surface of the bone and to produce bleeding.

When the recipient area has been properly prepared and all bleeding controlled, it should be packed with moist gauze and firm pressure applied while the bone graft is being obtained.

Obtaining the Bone Graft.—The crest of the ileum is an ideal source for the bone. An incision is made over the crest, beginning at the anterior-superior spine of the ileum and extending backward along the crest for a distance of about three or four inches. The incision is carried down through the periosteum, which is reflected with a sharp separator.

Using a sharp chisel, a number of thin shavings of dense bone are taken off the crest. The shavings should be at least as long as the greatest dimension of the wax pattern and should be no more than 2 or 3 mm. in thickness. When the spongy bone has been exposed, it may be removed with a chisel or sharp curette. My own preference is for a chisel.

All this material, both dense shavings and cancellous bone, is carefully wrapped in moist gauze and set aside. The bone grafts should not be left exposed to the air but should be kept in a covered receptacle and always in some definite place so that there is no chance of the graft being lost through carelessness.

When sufficient material has been obtained, the donor area is closed in the usual manner by the assistant, while the surgeon proceeds with the insertion of the bone graft.

Inserting the Bone Graft.—Hemostasis should be complete before the graft is inserted in the recipient area. The cancellous bone is cut into small pieces with a bone-cutting forceps or a heavy pair of scissors. These pieces should be a few millimeters in size. They need not be regular, but it is important that they be small. A large curette makes a convenient instrument to use as a spoon to ladle the spongy grafts into place. The precise amount of cancellous bone to be used requires some experience in gauging. As a general rule, if one is uncertain as to just how much bone should be inserted, it is better to use a little too much and then press out the excess by applying the lead mold gently before suturing the skin.

When sufficient cancellous bone has been deposited, one is ready to use the thin shavings of bone. These should be inserted over the cancellous grafts, immediately beneath the surface of the skin, so that they will conceal any slight irregularities that might result if the small pieces were left in direct contact with the skin. It will be necessary to trim these shavings to the proper size and shape, and this can easily be done with a heavy pair of scissors or a bone cutter.

The recipient area is then ready to be closed and for skin sutures whatever material one prefers may be used.

The molded splint is applied after closure is complete. Experience has shown that a thin layer of stent, or dental modeling compound, placed beneath the lead plate acts as a cushion and will prevent the metal from cutting into the skin at the edges. Moreover, the skin seems to tolerate the stent better than it does the naked metal. The stent is sterilized by boiling for at least twenty minutes. It is rolled out into a thin sheet, using the piston of a 30 c.c. glass hypodermic syringe on the softened stent, in much the same fashion as a housewife uses a rolling pin to roll out a mass of dough. The sheet of stent should be no more than a few millimeters in thickness. When the thin sheet

has been obtained, it is placed on the undersurface of the metal splint, trimmed to shape, and applied to the operative area while the stent is still soft but not hot enough to damage the skin. Before applying pressure bandage over the splint, it is well to make a final inspection of the operative area to be certain that it has been molded properly.

The pressure bandage should be carefully and evenly applied, but must not be tight enough to damage the skin. In suitable areas, bias-cut muslin bandage is excellent. Elastic adhesive tape is another good material for a pressure bandage.

POSTOPERATIVE CARE

The mold should remain in place for approximately four or five days. If suture marks are feared, sutures may be removed earlier and the mold replaced. In average cases, immobilization for from seven to ten days appears to be quite sufficient. In some instances, five or six days have been adequate. Areas like the chin, where there is considerable movement of the soft tissues, should be immobilized for a longer period (an additional week or so).

No postoperative complications have occurred in my series of cases. The earliest graft was done in 1942, and there has been no change in contour. The graft consolidates well, and after a period of about one month is firmly united in place. But no immobilization is required beyond the brief period outlined. I have had occasion in one case to excise the scar three months after the bone graft had been inserted. At the same time I smoothed down a slight fullness of contour. The bone bled freely and was certainly viable.

SUMMARY AND CONCLUSIONS

A new and simplified technique for bone grafting has been described. The indications for its use and the limitations have been pointed out. This type of graft is advocated as a contour restoration and not for functional purposes. This bone graft utilizes many minute pieces of cancellous bone covered with thin shavings of cortical bone, which are pressed into shape and immobilized by a mold which is prepared before operation. The simplicity of the procedure and the highly satisfactory cosmetic results obtained indicate that this type of graft has a definite and useful place in the armamentarium of the plastic surgeon.

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NYLON BONE SUTURE

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A SUTURE for bone is often needed when rigid fixation is impossible or undesirable. Such a suture must be strong, somewhat elastic, and not absorbable since osseous structures are slow in healing. Fascial or tendon sutures have been used successfully although the technique of introduction is, at times, difficult and an additional incision for the donor material is required.

Nylon is a strong, inert, semielastic nonorganic, radiolucent suture material which is well tolerated, both for cutaneous and buried sutures. When left in position it seems to offer advantage in certain instances over other known suture material, including wire. Nylon bone suture has been found to be very satisfactory for several different applications.

Many methods have been recommended for the treatment of acromioclavicular separations. Mumford¹ has advised resection of the end of the clavicle for cosmetic improvement and this procedure, associated with repair of the coracoclavicular ligament, has proved very simple and satisfactory. Through the small incision necessary to resect the clavicle a ligature carrier is passed around the coracoid process and four strands of heavy nylon are then passed from the clavicle about the coracoid. Function can be instituted almost immediately, thus preventing the secondary limitation of shoulder motion which often follows surgical procedures about the shoulder.

The treatment of hallux valgus and bunions is often difficult and, as pointed out by Lapidus,² a primary cause of recurring deformity is often persistent metatarsus primus varus. A satisfactory treatment for the bunion itself is a Mayo bunionectomy with arthroplasty. If the varus of the first metatarsal is then corrected, very little evident shortening of the extremity appears. The passage of a doubled nylon suture about the second and first metatarsals to maintain approximation at the distal end affords a rapid simple method of overcoming the varus and allowing early functional exercises in the postoperative period.

Heavy nylon sutures are efficient and well tolerated in the repair of fractured patellae. This is particularly true of the technique in which the distal comminuted fragments are excised and the patellar tendon is sutured to the proximal patellar fragment after repair of the lateral capsular tears. Care must be used to bury the knot in the tendon substance to prevent later palpable nodules in the thin subcutaneous tissue overlying the patella. With this technique, active exercise is begun three weeks after operation since the tendon heals in this time and no additional delay is necessary for bone healing.

At times, it is desirable to maintain multiple fragments of cancellous bone in position from the time of conclusion of the operation to the time of completion of the cast. It may insure better position of the foot to insert intertarsal sutures in the common simple triple arthrodesis to maintain position until

application of the cast and it is often helpful to use such intertarsal sutures in major reconstruction of the foot to maintain the desired position until external fixation is applied.

Long bone fractures may be held in approximation by heavy nylon suture if plate or other internal fixation does not seem indicated. This is true in the occasional forearm fracture of children, which requires open reduction to allow perfect function. Also in comminuted fractures of the femur or humerus in adults when the large central fragment cannot be maintained satisfactorily, particularly in compounds, a single nylon suture at either end of the fragment will maintain apposition until traction or cast is applied.

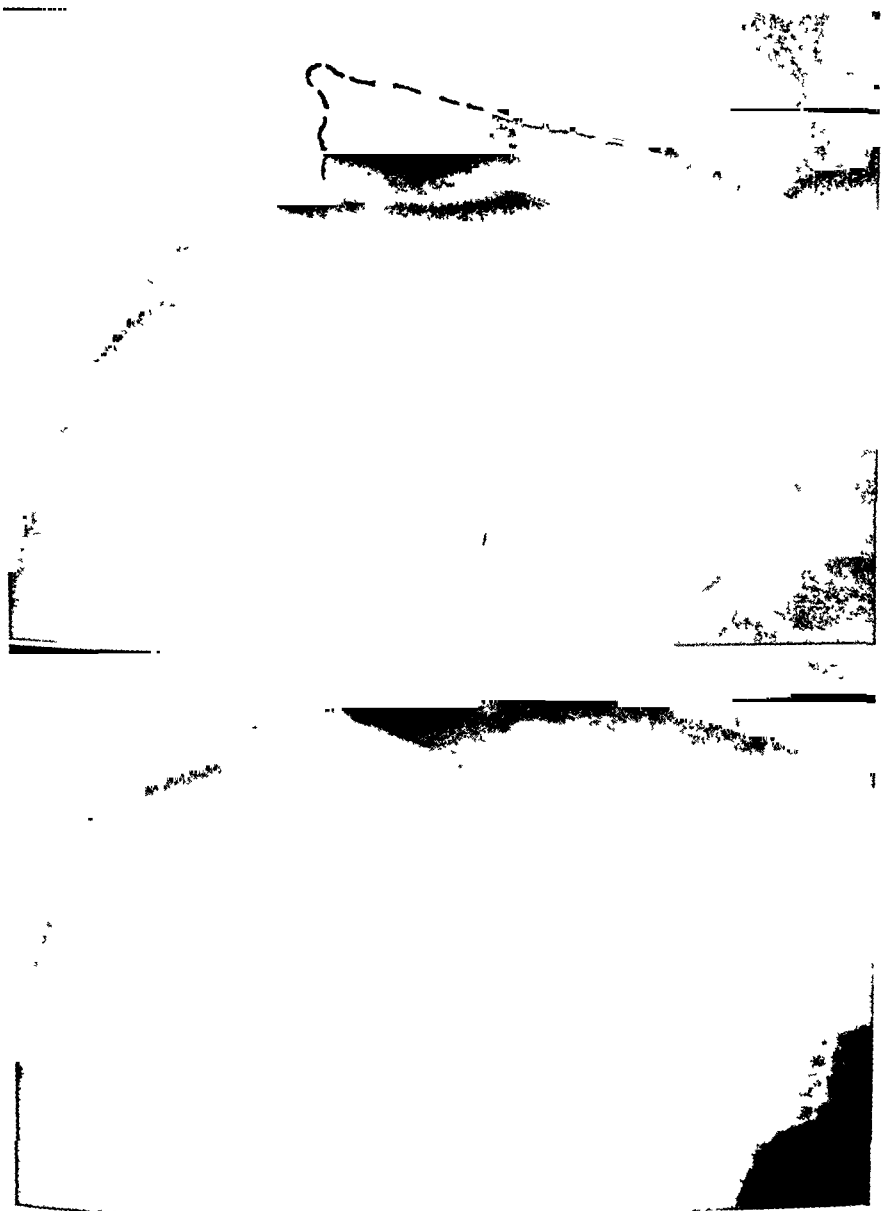


Fig. 1.—Acromioclavicular dislocation, chronic. X-ray pictures were taken before and after resection of the end of the clavicle and nylon bone suture, clavicle to coracoid.

If nylon is used, it must be fresh, strong, and resilient. Some preparations become brittle with age and are unsatisfactory. Sealed ampules, which are broken at the time of surgery, have been found most satisfactory for this work.

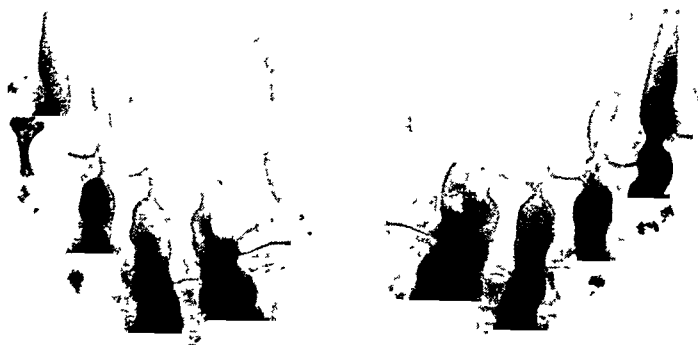


Fig. 2.—Hallux valgus with metatarsus primus varus, bilateral. X-ray pictures were taken before and after operative correction by Mayo bunionectomy and orthoplasty. Position of the left first metatarsal was maintained by nylon bone suture about the first and second metatarsals. The right first metatarsal without suture presents some persistent varus deformity.

TARSAL BONE SUTURE

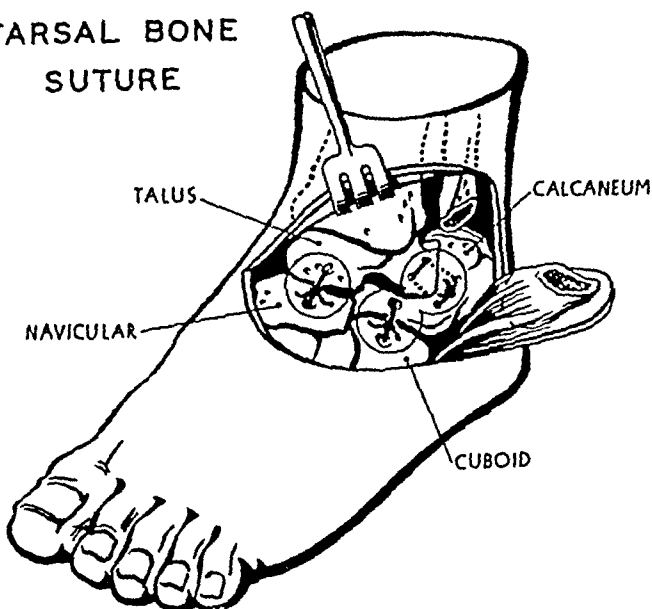


Fig 3—Diagrammatic representation of intertarsal suture following triple arthrodesis



Fig 4—Compound fracture of the left femur in young woman seven months pregnant. X-ray pictures were taken before and after débridement with nylon bone suture to maintain apposition of middle loose fragment. External skeletal splint was applied which was not satisfactory and Hodgen suspension traction was later applied with continued bone approximation during and after delivery.

SUMMARY

Bone sutures of strong resilient nylon are practical and desirable in certain instances. Techniques of repair of acromioclavicular separations, metatarsus primus varus, fractured patellae, intertarsal sutures following reconstruction operation, and maintenance of position of loose compound long bone fragments have been presented.

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HERNIATION OF NUCLEUS PULPOSUS; REFINEMENT IN OPERATIVE TECHNIQUE

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INTRODUCTION

WE HAVE recently called attention to certain technical considerations in the surgical management of lumbar herniated nucleus pulposus that we feel have done much to minimize numerous postoperative residuals.² The evolution of treatment for this condition has been directed mainly toward simplification of the operative technique. Originally, laminectomy with transdural removal of the disc was employed. Later, hemilaminectomy, then partial hemilaminectomy, was performed with an extradural approach to the interspace. Advancement continued so that many neurosurgeons now prefer a unilateral, interlaminar, extradural exploration,¹ without removal of bone and with curettage of the disc space. Section of the sensory root to control postoperative pain is no longer practiced.

Some observers have stressed the importance of hypertrophy of the ligamentum flavum in production of nerve root pressure with or without an associated disc. This has been contrary to our experience as will be indicated.

Although the importance of an unstable joint in the production of symptoms has been recognized, fusions have rarely been performed on our service because they necessitate prolonged additional hospitalization. This plan has not materially altered our end results. Only 5 cases in 261 (1.9 per cent) have, to our knowledge, required fusion, either at the time of disc removal or at a later date.

A number of our patients have continued to complain postoperatively of severe low back pain with sciatic radiation which we could not entirely explain on the basis of incomplete removal, recurrent or multiple discs, unstable joints, irreversible changes in the nerve root due to previous pressure or operative trauma, or associated pathology, such as tumor, arachnoiditis, etc. Twelve of this group, ten of whom were from our earlier series, were re-explored in an effort to explain the continued symptomatology at varying intervals from one to thirteen months, following the primary operation. All showed dense adhesions

extending from the paraspinal muscles and margins of the previously resected ligamentum flavum to the dura and adjacent nerve root with definite constriction of the latter. Four also showed a second disc which contributed to the residual discomfort, but three were on the opposite side of scar formation. In these men there had been bilateral sciatica. One case showed a true recurrence. Our present operative technique has been directed toward the prevention of the postoperative reaction described. This has been accomplished satisfactorily by the following method.

TECHNIQUE

The operation has been performed in all cases with the patient placed in the prone position. A small midline incision is made extending between the spinous process at the site of the lesion and the one immediately below. A unilateral exposure of the ligamentum flavum in the affected interspace and the lamina above and below this level is then accomplished. Bilateral exploration is used only if the symptoms, signs, and spinogram indicate its necessity. Gauze sponges may be packed in the superior and inferior angles of the wound. This controls muscle bleeding and facilitates exposure. The table is then broken to flex the joints of the spine and further simplify the approach. Very rarely is it necessary to sacrifice any bone from the laminar margins. Sufficient bone may, in such instances, be removed with a curette or Kerrison mastoid punch.

The usual technique at this point has been altered to insure preservation of the ligamentum flavum. This is done by incising, carefully, through the ligamentum along its line of fusion with the interspinous ligament close to the midline. Then with a No. 2 curette, it is gradually dissected free from the adjacent superior and inferior laminar margins. The lateral attachment is preserved (Figs. 1*b* and 2*c*). For illustrative purposes, the nerve root is shown displaced laterally by the disc, whereas actually, medial dislocation is more commonly seen. The ligamentum flavum has thus been preserved and is retracted during the operation, preferably by a silk suture attaching it to the adjacent paraspinal muscles.

The dura and nerve root are then carefully retracted medially. If the nerve root is displaced laterally by the lesion it can usually be moved over the herniated nucleus pulposus to a medial position. Rarely is it necessary to attack the lesion through the angle formed by the nerve root and dura, an inconvenient and somewhat dangerous operative tract. Small squares of cottonoid may then be placed in the interval between the dura and lateral wall of the canal to control bleeding and assist the medial displacement of dura and nerve root. (Each square of cottonoid has a silk suture attached to prevent retention in the spinal canal.)

Rupture of the intervertebral disc is often seen with free extradural extrusions. In such cases, the fragments can be removed with the forceps or any suitable instrument. Occasionally (Fig. 1*a*), it is necessary to incise the annulus fibrosus and posterior longitudinal ligament. The contents of the disc are then removed by means of the pituitary rongeur (Fig. 2*d*). The disc space is thoroughly but cautiously curetted. The ligamentum flavum is then easily replaced (Fig. 2*c*) at the conclusion of the intraspinal portion of the procedure after the patient has been extended to the horizontal position. A suture may rarely be necessary to restore complete anatomic continuity.

The alternate method previously described is now being reserved only those cases in which the ligament cannot be preserved for technical reasons

secondary procedures on patients operated on elsewhere in which the ligament had been sacrificed. In this procedure, the ligament is completely removed. Routine disc removal is accomplished as previously described. After hemostasis is secured, a small section of tantalum foil is fashioned slightly larger than the exposed interspace. It is then inserted beneath the interlaminar margins into the area previously occupied by the ligament. A small dental periosteal elevator will do much to facilitate this part of the procedure.

Preserving the ligamentum flavum appears to be the more physiologic method as further demonstrated by re-exploration in two men in whom each alternate procedure had been performed.

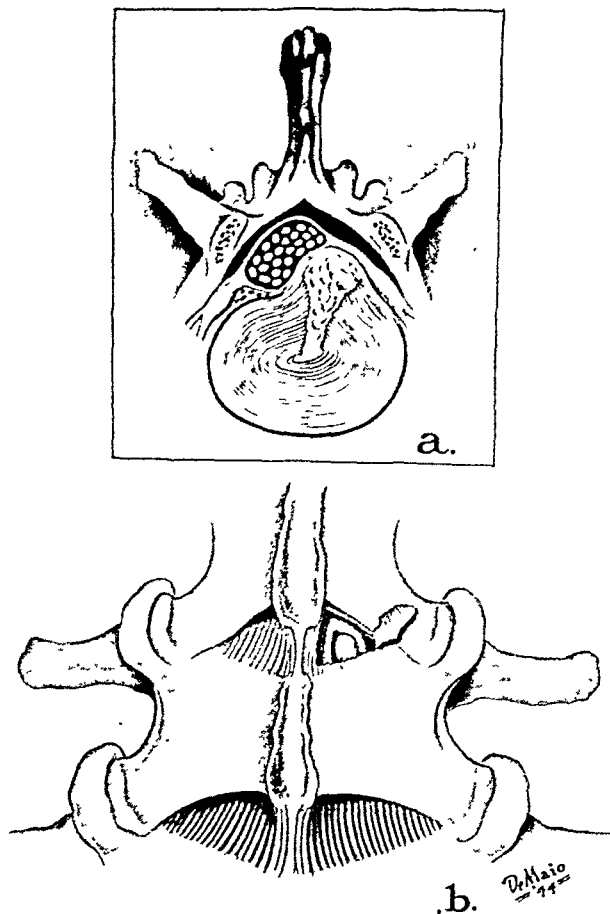


Fig. 1.—*a*, Protrusion of nucleus pulposus causing nerve root pressure. *b*, Retraction of ligamentum flavum laterally.

In one case tantalum foil had been used and scar tissue was found between the muscles, dura, and nerve root. The foil was found superficial to the laminae rather than between the dura and bone as is necessary to prevent the formation of adhesions about the nerve root.

Lumbar 4 and 5 interspaces were explored in another case and only the lumbosacral disc was curetted. The higher disc was judged to be borderline so it was spared, in spite of a small lesion evident on pantopaque myelogram. The ligamentum flavum was preserved in both interspaces. The patient received no relief, so that six weeks later Lumbar 4 disc was found to present a midline

protrusion and was curetted. The ligamentum flavum was reflected from both interlaminar spaces previously explored. The incised borders of the ligamentum flavum in both instances had reunited solidly with the laminar margins and the interspinous ligament medially and required removal in the same manner as originally. The underlying dura and epidural fat were normally smooth and glistening. There were some adhesions about the nerve root in the lower interspace where the disc had been removed at first operation. These were found between the nerve root, dura, and epidural tissues in the anterolateral angle of the spinal

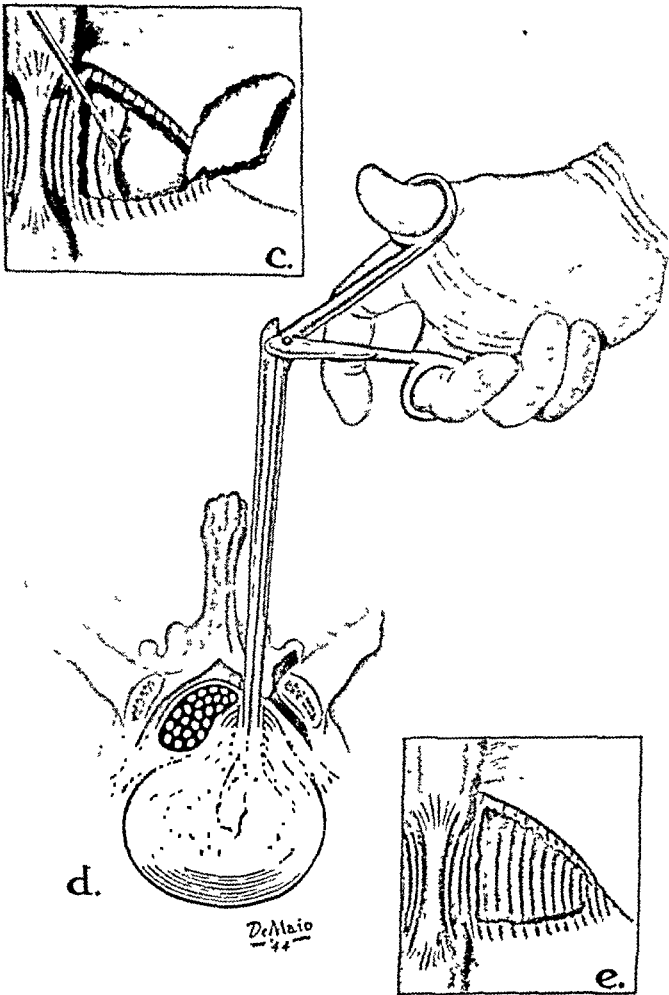


Fig. 2.—c, Retraction of nerve root medially showing subjacent disc herniation. d, Removal of disc fragments with a pituitary rongeur. e, Replacement of ligamentum flavum following disc removal.

canal. The nerve root in the upper interspace was free of any recognizable adhesions although Lumbar 4 disc had been explored but not curetted at former operation. Preserving the ligamentum flavum thus prevented the formation of scar tissue between the contents of the spinal canal and the paraspinal muscles. It cannot be expected to modify adhesions between the nerve root and adjacent structures within the canal. Adequate hemostasis, careful handling, and atraumatic retraction of the nerve root during operation should reduce the incidence of this type of reaction.

RESULTS

From June 8, 1942, until May 1, 1945, we operated upon 261 patients for herniated nucleus pulposus. Pantopaque myelography was used in all cases to confirm the diagnosis and a lesion was verified in 257, of these patients, 84.2 per cent have returned to a useful form of military duty, usually two to three months following operation.

There were seventy-three cases prior to our change in operative technique in July, 1943, and 76 per cent of the men in this group returned to duty. Since this time there have been 188 cases and 97.8 per cent of these men have been discharged to limited or general military duty. The ligamentum flavum was preserved in 151 and tantalum foil substituted for it in 37 prior to our restriction in technique to the former method.

We do not claim that this technique solves the disc problem, but certainly since its introduction the patients have made better progress, although it is appreciated that to date we have had no opportunity to follow our cases over long periods of time for obvious reasons.

SUMMARY

We have described a variation in the present operative technique for herniated nucleus pulposus which has given fewer postoperative sequelae and improved results in our experience. This consists of preservation of the ligamentum flavum with replacement at the conclusion of the procedure. Our purpose has been to prevent the formation of adhesions extending from the paraspinal muscles and resected ligamentary edges to the dura and adjoining nerve root, which through traction on these structures when the spine undergoes movement not infrequently produces pain as a residual of operations for removal of herniation of the nucleus pulposus.

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CHYLANGIOMA CAVERNOSUM MESENTERII

REPORT OF A CASE AND REVIEW OF THE LITERATURE

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TUMORS of the lymph vessels belong to the rarest of neoplasms. Clinically, when they occur they are usually associated with a distinct entity, as, for instance, macroglossia, macrocheilia, lymphangioma cysticum of the neck, or hygroma cysticum colli.

Lymphatic tumors may occur in the rich lymphatic supply of the mesentery where they are known as mesenteric lymphangiomias. These are classified into the same groups as are lymphangiomias in general:

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1. Lymphangioma simplex, which is a single network of dilated lymph vessels and spaces.
2. Lymphangioma cystoides, which consists of multiple isolated cysts which have lost their connection with the lymphatics.
3. Lymphangioma cavernosum, which consists of numerous communicating cavities which are separated by thin septa.

In the mesentery, lymphangioma cavernosum is the least common of the lymphatic tumors. Nevertheless, it exhibits a distinctive pathologic picture. In 1875, Weichselbaum¹ described such a case and because of its origin and intensive involvement of the lacteals he termed it a chylangioma cavernosum. Since then four additional cases have been described. The following is a case report of the sixth known case.



Fig. 1.—Gross specimen. The cystic tumor involves the entire width of the mesentery and projects into the lumen of the bowel.

CASE REPORT

Clinical History.—A 20-year-old white man had a sore throat for several days. Two days prior to admission to the hospital he noted abdominal pain in the region of the umbilicus. Later he had diarrhea, nausea, and vomiting. In the afternoon preceding admission the pain subsided somewhat but localized in the right lower quadrant of the abdomen.

On examination the patient appeared acutely ill. The abdomen was moderately distended and tender with rigidity over McBurney's point. The temperature was 39.5° C., respiration 22, pulse 100. The urine showed 1 plus albumin. The white blood count was 35,000 with 95 per cent polymorphonuclear cells of which 19 per cent were stab cells. At operation some brownish-red fluid was present within the abdominal cavity and the peritoneal surfaces were brownish red in color. About two feet proximal to the ileocecal valve a mass was found in the mesentery of the ileum. After the surrounding adhesions were removed it was found that the portion of the bowel proximal to the mass was dilated and the distal portion collapsed. The mass had encroached upon and completely compressed the lumen of about one and one-half feet of bowel. After resection of the loop of bowel and attached mesentery with the tumor, a side-to-side anastomosis was performed and an ileostomy tube inserted. Sulfanilamide powder was dusted into the abdominal cavity. In spite of supportive

treatment the patient developed jaundice and two days subsequent to surgery died of ileus and peritonitis.

Pathologic Report.—On gross examination (Fig. 1) the specimen was found to consist of a loop of bowel measuring 45 cm. and the entire attached mesentery. Spreading in a fan-shaped fashion, with the angle toward the root of the mesentery, there was a large tumor, measuring 12 by 10 cm. between the leaves of the indurated mesentery. Bulging over the surface, numerous oval and round-shaped, bluish and brownish cysts projected. These were smaller near the radix mesenterii but within the fatty tissues the lymph nodes were enlarged. The entire serosa was covered with fibrin, and was dull, with areas of focal hemorrhage. As the lumen of the bowel was opened it was found to be partially filled with a soft fecal material and mucus. A cluster of small clear cysts, the largest of which measured 8 mm. in circumference, projected from the mucosa into the lumen over an area of about 4 cm. When these cysts were sectioned, it was found that they were multiple, intercommunicating, varying in size from several millimeters up to 3 cm., containing either a milky or a curdlike fluid, clotted blood, or a mixture of these. Smears taken from the contents of the cysts showed streptococci, pus cells, and red cells.



Fig. 2.—Microscopic specimen, section through mucosa. Numerous, irregularly shaped intercommunicating spaces, filled with chyle, comprise the tumor.

Microscopically (Fig. 2) the lacteals of the villi showed varying degrees of dilatation forming rounded and irregular cystic spaces. These were separated by thin septa, were lined with a flattened single layered epithelium, and contained a precipitated pinkish material. In the submucosa these spaces were enlarged and were anastomosing. Similarly, some of these spaces could also be found within the muscularis and serosa. The larger spaces were, for the most part, filled with hemolyzed blood or collections of polymorphonuclear cells. The stroma in the mesentery was comprised entirely of fatty tissue and connective tissue in which an occasional histiocyte, polymorphonuclear cell, or collections of lymphocytes were seen. A germinal follicle within the submucosa showed numerous small spaces and slits between the lymphocytes. Sections from the root of the mesentery merely showed occasional dilated lymph channels and considerable collections of polymorphonuclear cells.

At autopsy, not much was added to the known facts. In the vicinity of the surgical procedure there was a localized peritonitis. Remnants of sulfanilamide powder were still present within the abdominal cavity. The loops of bowel proximal to the surgical site were markedly distended and filled with a fluid fecal material. The distal portion was collapsed. The surgical anastomosis was intact and the ileostomy stoma was adequate. The diaphragm on both sides was elevated causing basilar atelectasis of the lungs. In addition, the lungs were congested and edematous. The liver was considerably enlarged and showed extreme parenchymatous degeneration. The spleen and kidneys showed changes associated with an

acute inflammatory process. Except for the lymphatic hyperplasia of the Peyer's patches, the gastrointestinal tract was essentially normal. Microscopic examination of the tissues revealed nothing of significance.

REVIEW OF PREVIOUSLY REPORTED CASES

Five strikingly similar cases have been previously described. These are listed briefly here and it will be seen how closely they resemble each other.

1. *Case of Weichselbaum.*¹—As an incidental finding in the autopsy of an 80-year-old man who died of pneumonia and scurvy, a 3 to 4 cm. sized tumor was found in the fatty portion of the mesentery. This tumor consisted of numerous anastomosing cavities of varying size which contained a milky fluid. The smaller spaces were lined by a flat endothelium. Connective tissue was abundant. In the fatty tissue, collections of round cells could be seen between which spaces were formed resembling fine lymph channels. These communicated with the larger cavities. Because, chemically, the milky fluid proved to be chyle, this tumor was called a chylangioma.

2. *Case of Kruse.*²—Also as an incidental finding at the autopsy of a 75-year-old man, multiple small lymphangiomas were found in the wall of the jejunum. Grossly and microscopically, these resembled the previously described case.

3. *Case of Vautrin.*³—A 30-year-old woman, suffering from rheumatic fever, noted a tumor mass in the abdomen which had been gradually enlarging over a period of one year. Shortly before admission she complained of diarrhea and coliclike pains. At laparotomy a tumor was found to be located in the mesentery of the jejunum, adherent to the surrounding loops of bowel, measuring 6 to 7 cm. in size, fan-shaped, with the angle toward the spinal column. Fifty centimeters of bowel were resected with the tumor. Grossly it consisted largely of fatty tissue with numerous anastomosing cavities. Many multilocular cysts also bulged into the lumen of the bowel so that the wall of the bowel as well as the mesentery was involved.

4. *Case of Takano and Hauser.*⁴—A 22-year-old pregnant woman presented herself with a mass in the right side of the abdomen of one year's duration. She had no complaints other than of a stomach-ache of four days' duration. At laparotomy the tumor was found to be the size of a man's head, located within the mesentery of the small intestine. Grossly the tumor measured 14½ cm. and the loop of bowel removed, 35 cm. The entire mesentery was occupied by the tumor. Numerous cavities containing a milky fluid in a network of connective and fatty tissue made up the tumor. The mucosa of the bowel was swollen and numerous cysts bulged into the lumen. Microscopically, the cavities were lined with flattened endothelium and communicated with each other. Muscle fibers could also be found within the connective tissue. Within the mucosa the lymph spaces were enormously dilated. The lymph nodes within the mesentery showed spaces which connected with the larger dilated cavities.

5. *Case of Puppel and Morris.*⁵—An anemic 55-year-old woman complained of weakness and bloody stools. At laparotomy a mass was found in a loop of jejunum. Grossly the tumor measured 6 cm. and the jejunum removed measured 25 cm. Within the mucosa, a large fungating mass made up of numerous small nodules was found to project 1½ cm. above the wall. The serosal surfaces showed numerous similar nodules. Microscopically, these nodules were comprised of cystic spaces lined with endothelium. They contained pinkish-staining material. The spaces extended up into the epithelial cells lining the mucosa.

SUMMARY OF REPORTED CASES

These tumors may occur in either sex, and to date have been found only in adult individuals within the mesentery of the small intestine. They may reach considerable size before symptoms are manifested. Obstruction, infection, or bleeding is the pathologic basis for clinical symptoms. These may be indefinite, consisting of swelling, pain, or blood in the stools. At laparotomy a tumor is found within the mesentery of the small intestine which can be of any size. It may occupy the entire width of the mesentery and extend into the lumen of the bowel. The cysts contain chyle and communicate with each other.

they may contain blood, either because the tumor may include blood vessels or because the tumor may rupture those blood vessels already present. In case of infection, as in our case, blood and pus may fill the lumen of some of the cysts. At surgery, resection of the tumor and the adjacent loop of bowel is usually performed.

PATHOGENESIS

Lymphangiomas may occur as a result of two causes, obstructive or neoplastic. Obstruction may cause a congestive ectasia. Although on first consideration it would seem that most angiomas are on this basis, apparently it is an uncommon cause. Most of these tumors are apparently neoplastic. Two sources exist from which the tumor may arise. In the rarer form, homoplastic neoplasia, proliferations of lymphendothelium occurs forming spaces which communicate with the pre-existing lymph vessels. The more common form, heteroplastic neoplasia, develops from a connective tissue matrix. Weichselbaum¹ and Takano and Hauser,⁴ after considering all the possibilities, judged their tumors to be of this latter type. They believed that within the fatty tissue around the blood vessels, islands of lymphocytic infiltrations occur. Between these cells spaces develop which communicate with pre-existing and newly formed lymphatics. Subsequently, the round-cell infiltrations are converted and build the fibrous portion of the tumor.

DISCUSSION

Chylangioma cavernosum mesenterii is a benign tumor which occurs in the mesentery of the small bowel. Depending upon size and position, symptoms of a tumor or bowel obstruction may present themselves. Erosion and bleeding are other possible complications. In the cases of Vautrin³ and of Takano and Hauser,⁴ a tumor mass was evident clinically and symptoms of chronic bowel obstruction occurred. In the case of Puppel and Morris,⁵ the anemia, due to the bleeding into the lumen of the bowel from the tumor, was the cause of clinical symptoms. In our case a superimposed infection, presumably following a sore throat, was the cause of initiation of symptoms. The secondary infection caused the increased size of the tumor which then caused the obstructive ileus. Apparently then, clinical symptoms are absent unless either infection, obstruction, or hemorrhage occurs.

Pathologically, the case we are reporting is identical to those previously described. Except in the case of Weichselbaum,¹ all of the tumors included the mucosa of the intestinal wall. Grossly and microscopically they are all similar. The origin of lymphangiomas is still obscure. It is impossible to add much to the previously mentioned concepts of the development of these tumors. Sections in our case were taken from the mesentery but the lymph node involvement mentioned by Weichselbaum¹ and Takano and Hauser⁴ was not found, largely due to the extensive encroachment of the tumors upon these nodes. However, the lymph follicle found within the submucosa showed the slits mentioned by these authors. In this case, it would seem that the lymph follicles were secondarily involved and that the widening of the channels was part of the dilatation that occurred within all of the lymphatics. The exact derivation of this tumor is, therefore, still questionable. No obstruction was found at the root of the mesentery which might conceivably cause a congestive dilatation of the lymph vessels. The infection was too acute to be a causative mechanism. It was entirely secondary and superimposed on the pre-existing tumor.

SUMMARY

1. Five cases of chylangioma cavernosum mesenterii are reviewed and an additional case is presented.

2. These are benign tumors occurring in the vicinity of the small bowel and originating from the lymphatic tissue.

3. Although often silent, they may cause symptoms of obstruction or hemorrhage, or be the site of secondary infection.

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A METHOD OF RETAINING AN INTRAVENOUS NEEDLE IN SITU

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TODAY intravenous therapy is a daily part of many surgical and medical treatments. It is featured in the treatment of shock, in the prevention of shock, and in the administration of many medications, elements of nutrition, and anesthetic agents.

There are many techniques used in attempting to fix intravenous needles in situ. The difficulties met in keeping the needle in place are due to the varied topography and musculature of the arm or leg used, the various positions in which the member must be held, and the varying depths and directions of the veins themselves. The needle should be held in the vein at the angle and in the direction conducive to fastest flow.

The method described here requires only adhesive tape as the immobilizing agent. The operator may employ his usual needles and technique of venepuncture. Though it is no panacea, it has been found to be simple, effective, and reliable in most instances. The technique is as follows:

1. The needle is inserted into the vein in the operator's usual manner and it is then held by the hub with the left hand (Fig. 1) at the angle and in the direction giving the greatest rate of flow as seen by the drip apparatus.

2. A piece of adhesive (Fig. 1), previously cut, two inches long and one inch wide is then applied at right angles to the shaft of the needle, one inch of the length being on either side of the shaft and one-half of the width of the tape overlapping the needle shaft, the remainder of the width applied to the adjacent skin as a light anchorage.

3. With this anchorage in place and the needle still held by the thumb and forefinger of the left hand at its hub, a wider and longer strip of adhesive approximately two by four inches is allowed to drape loosely (Fig. 2) over the tubing adjacent to the hub. This tape is applied so that its length is bisected

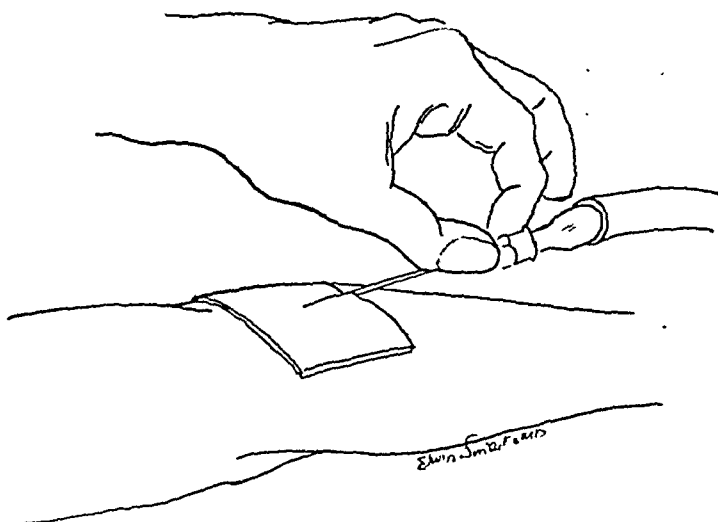


Fig. 1.—The needle has been introduced into the vein; its shaft is secured to the skin by adhesive tape.

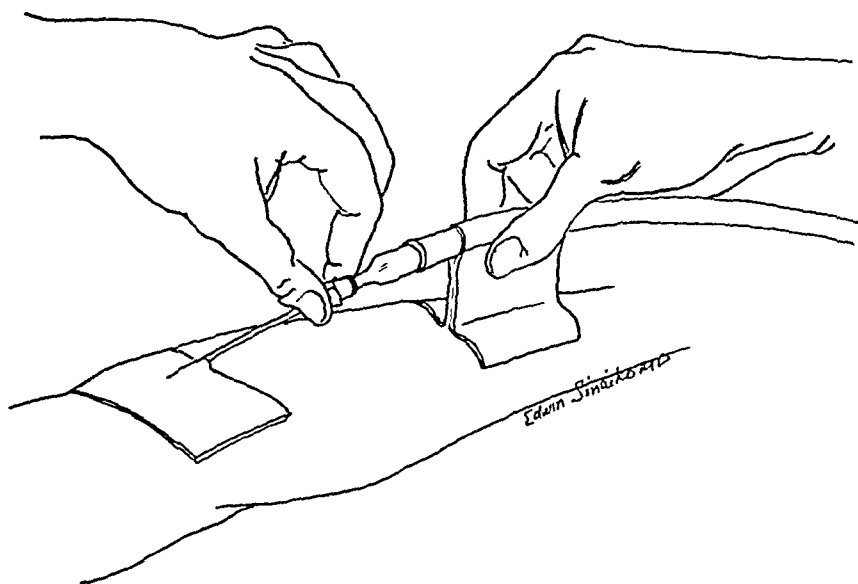


Fig. 2.—With the left hand holding the hub of the needle, the first piece of adhesive has been applied between the tubing and the skin.

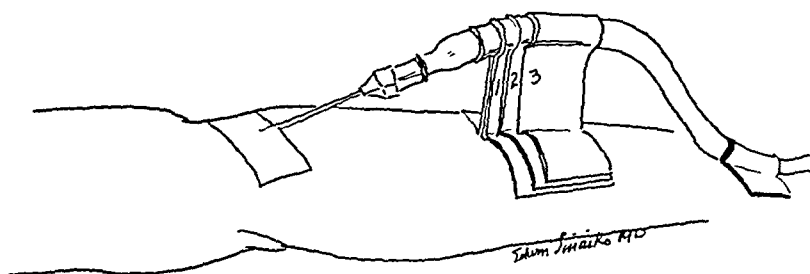


Fig. 3.—The intravenous needle is now immobilized well; 1, 2, and 3 show the several layers of adhesive used to add rigidity and immobility.

by the tubing. The tape is then molded around the tubing and its adhesive surfaces between the tubing and skin are stuck firmly together. The two free ends of the tape are then applied to the skin, each on its respective side, allowing them to take whatever direction they will to conform to the topography and contour of the arm.

4. As a final touch and to add rigidity and firmness, layer upon layer (Fig. 3) of adhesive may be applied until the desired immobilization and stability are attained. The tubing distally may be secured to the arm by a single piece of adhesive in the usual manner.

CONCLUSION

1. A method of retaining an intravenous needle in its optimum position of function is described.

2. This method is applicable to any technique of venepuncture and uses only adhesive tape in its performance.

3. With this method the needle-tubing connection is not concealed and the two may be uncoupled and reconnected expediently and quickly.

Book Reviews

Arterial Hypertension. Its Diagnosis and Treatment. By Irvine H. Page, M.D., and Arthur Curtis Corcoran, M.D., Cleveland Clinic Foundation. Ed. 1. Pp. 343. Chicago, 1945, The Year Book Publishers, Inc. \$3.75.

The authors have succeeded in presenting a well-rounded review of a large and important subject. One of the commendable features of this book is the sound, common sense attitude expressed on the aspects of the problem which still remain controversial. The section on electrocardiography contains one error (p. 147, the standard leads) and is not very clear in its differentiation between the pattern of left ventricular strain and anterior myocardial infarction. The sections of the book on therapy are particularly worth while.

Minor Surgery. By various authors, edited by Humphry Rolleston and Alan Moncrieff. Ed. 1. Pp. 174, with 30 illustrations. New York, 1944, Philosophical Library, Inc. \$5.00.

This small book is in the nature of a handbook and guide for the general practitioner who does only minor surgery. Procedures of greater moment are specifically omitted and relegated to the surgeon. The book suffers from three faults, absence of enough good illustrations, inadequate references to the literature, and a somewhat spotty choice of subjects for discussion.

Despite these shortcomings of this volume, it contains a wealth of sound information in concise and readable form. Such items as management of lacerations, hand infections, greenstick fractures, sprains, etc., are well discussed. It is a welcome addition to the library of the general practitioner.

Vascular Responses in the Extremities of Man in Health and Disease. By David I. Abramson, M.D., The University of Chicago. Pp. 412, with 59 illustrations. Chicago, 1944, University of Chicago Press. \$5.00.

Abramson has compressed into 300 odd pages a wealth of information ranging from the elementary anatomic and physiologic characteristics of the vascular system of the tests of function available, and the alterations produced by the various disease entities to which the peripheral vascular tree is subject. This is a complete and scholarly presentation. It is well edited and indexed. The general practitioner, as well as the neuro- or vascular surgeon, can find in it either precisely what he wants to know, or references to the literature where he can find what he seeks. Measures of therapy of certain peripheral vascular conditions may also be found in this volume.

This is a precise, readable, up-to-date, and almost complete review of the subject. It should be an essential part of the education of anyone interested in vascular diseases.

Textbook of Surgical Treatment Including Operative Surgery. By C. F. W. Illingworth, M.D., Ch.M., Regius Professor of Surgery, University of Glasgow. Ed. 2. Pp. 564, with 230 illustrations. Baltimore, 1944, Williams & Wilkins Company.

This book endeavors to cover the field of surgical therapy in 557 pages. Necessarily, it is incomplete. Many subjects are mentioned only to be dismissed in a few words.

In general, the impression is left that oversimplification has been attempted. For instance, there is no word on the diagnosis of thrombophlebitis, and the treatment is very briefly outlined as continuous infusion of heparin by vein and immobilization of the extremity. There is no mention of the precautions to be taken in heparin administration by this means, or of any alternative methods of therapy. Sympathetic nerve block and

proximal venous ligation are not mentioned at all. Postoperative anuria is discussed as if the sole problem were that of evacuating the bladder; renal failure is left untouched.

Throughout the book the inadequacy of preoperative study and diagnosis is glaringly apparent. Intestinal obstruction is referred to as an indication for exploration without mention of differentiation by history, physical examination, or x-rays between colic and ileac obstruction. Rib resection is advised for empyema thoracis without mention of methods to assure drainage at the bottom of the cavity.

All in all, the book impresses one as having been hurriedly prepared on the basis of narrow experience alone. Complete and up-to-date coverage of subjects is rarely found in it, and the subjects are presented in a manner too advanced for the beginner. The depth of study apparently involved in the preparation of the book is perhaps best signified by one bit of statistics:

Number of pages, 557

Number of references cited, 0

Endocrinology of Woman. By E. C. Hamblen, B.S., M.D., Springfield, 1945, Charles C Thomas, Publisher.

The first section of this book is a brief summary of the normal physiology and anatomy of all the endocrine glands. As such it adds little to the value of the book except possibly for teaching purposes.

The remainder of the book concerns the applied physiology, diagnostic methods, and functional disorders of the endocrine glands. A final section deals with the endocrinological aspects of gynecologic disease. It is here that the author has clearly presented one of the best, if not the best, summaries, of gynecologic endocrinology. The problem of sterility, its diagnosis and treatment, is handled well and in sufficient detail.

In some instances controversial subjects have not been completely presented. Nevertheless, they have been recognized and suitable references quoted.

Both author and publisher should be commended for the pleasing format. Illustrations, line drawings, graphs, and tables are abundant and especially well done.

This book can be recommended as an authoritative textbook for medical students and a reliable guide for the clinical practice of the endocrinology peculiar to women.

The Woman Asks the Doctor. By Emil Novak, M.D. Baltimore, 1944, Williams & Wilkins Company.

Those who were familiar with the first edition of this popular book will find the second edition generally similar but with many revisions which bring it up to date. Those who are not familiar with the work will find it to be a conservative, sound discussion of gynecology for lay women.

The reviewer submitted the book to several women whose educational background was approximately that of college level. Several had difficulty in understanding some of the discussion dealing with endocrinology, but aside from this they read the book with ease.

This book can be recommended by physicians as an authoritative work for use by lay people and it should be of especial value during these busy days when time does not always permit leisurely counseling of gynecologic problems.

Emergency Surgery. By Hamilton Bailey, F.R.C.S. (England). Ed. 5. Pp. 969, with 1039 illustrations. Baltimore, 1944, Williams & Wilkins Company. \$18.00.

This is an ambitious book, one which undertakes to discuss emergency situations from acute mastoiditis to pulmonary embolus, to compound fractures, to ruptured tubal pregnancies. With such a breadth of coverages as this, the adequacy of most of the sections is amazing; but unfortunately, in the incomplete revisions which have occurred, many portions have become sadly out of date or provincial. Collection of blood from donors by the old open method is still described. Tannic acid is the exclusive method of burn treatment recom-

mended, even on the face. Primary anastomosis in the presence of small bowel obstruction is decreed as commanding a 50 to 60 per cent mortality, a situation certainly no longer true since adoption of the closed methods which are not even mentioned. Many trade names of drugs (or provincialisms) are employed throughout the book. It is advised that exposed intestines be covered with *hot* saline towels, when well-controlled recent work has shown the tendency of this procedure to lead to adhesion formation. It is recommended that peritonitis be treated by cecostomy in many cases, a procedure long since abandoned in modern surgery.

In spite of the examples cited, there is a great amount of good advice and common sense to be found in this book. It is perhaps a good reference volume for those with a background in surgery, but there is so much archaic misinformation included that it is hardly to be recommended to the initiate. A thorough re-editing could make a very generally useful volume of this effort.

Announcement

Due to conditions beyond the control of the editors and publishers, several issues of the JOURNAL are printed on an inferior grade of paper. Just as soon as the standard good grade of paper is available, its use will be resumed.

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